

# An acoustic investigation of postaspirated stops in Seville Spanish

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## Table of Contents

Section 1: Introduction .....	3
Section 2: Literature Review .....	5
2.1 Previous Studies on /s/ Weakening .....	5
2.2 Previous Studies on /st/ Consonant Clusters in Andalusian Spanish. ....	18
Section 3: Research Objectives and Hypotheses .....	28
Section 4: Methodology .....	30
4.1 Participants.....	30
4.2 Stimuli and Procedure .....	32
4.3 Acoustic Analysis .....	33
4.4 Statistical Analysis.....	37
Section 5: Results.....	40
5.1 Postaspiration as a Binary Dependent Variable.....	40
5.2 Postaspiration as a Continuous Dependent Variable .....	43
5.3 Effect of Sibilant Realization on Postaspiration Duration .....	50
5.4 Correlation Relationships of Adjacent Segment Durations .....	56
5.5 Additional Results and Social Tendencies.....	59
5.6 Results Summary .....	66
Section 6: Theoretical Analysis .....	67
Section 7: Conclusion .....	81
Section 8: Appendix- Complete List of Stimuli .....	84
Section 9: Bibliography .....	85

## 1. Introduction

The purpose of this investigation is to analyze the phonetic mechanisms behind an innovative sound change currently occurring in the Andalusian region of southern Spain, specifically in the capital city of Seville. The weakening of the voiceless fricative /s/ in syllable final position to a breathy [h] is a common process in many Spanish dialects, often resulting in complete deletion of the segment. However in the Spanish spoken in the city of Seville, when preceding a voiceless dental occlusive, this frequent /s/ preaspiration is being realized as postaspiration and even occasionally as the affricate [t<sup>s</sup>]. This change of production from [st] > [ht] > [t<sup>h</sup>] > [t<sup>s</sup>] has become a distinctive dialectal feature of the region and has not been documented in any other Spanish consonant system (Ruch 2008). The purpose of this study is three-fold. First, to investigate the possible expansion of this phenomenon to the other voiceless occlusive consonants in Spanish, namely /p/ and /k/. Second, to determine the social and linguistic factors that condition the presence or absence of postaspiration. Finally, to situate this innovative realization in the theoretical model known as Articulatory Phonology in order to better explain the internal mechanisms conditioning this postaspiration process. The organization of this paper is as follows. The first section consists of an overview of the literature regarding general /s/ reduction throughout all dialects of Spanish followed by a review of the literature for this particular /st/ phenomenon in Andalusia, Spain. Next, section three explains the specific research questions for this study and the hypotheses posited, while section four discusses the methodology used for the study, including the profiles of the participants, the development and presentation of stimuli and the measurement guidelines used for the acoustic analysis. Then, section four presents the results of the study, including the statistical analysis done for both the social and linguistic factors investigated. Finally, section five presents a theoretical analysis of

the phenomenon within the framework of Articulatory Phonology and section six is the conclusion.

## 2. Literature Review

One of the most prevalent phonological processes in modern Spanish involves the reduction of the voiceless alveolar fricative /s/ in coda position to either aspiration, [h], or deletion of the segment, [Ø]. Weakening of /s/ to either of these two variants can be found in dialects of Southern Spain and throughout Latin America, while /s/ is typically maintained in its fricative form in parts of central Mexico, Guatemala, Costa Rica, the Andean region and Northern Spain (Campos-Astorkiza 2012). In those dialects where /s/ reduction is found, the precise realizations can also vary dramatically. Thus, this reduction process, often also referred to as weakening, aspiration or debuccalization, is not completely uniform and may be more or less restrictive depending on different dialects, linguistic contexts and social factors. To better understand the processes at work, this current section presents a detailed description of the fricative /s/ in both articulatory and acoustic terms. Then, Section 2.1 explores the process of reduction of this particular fricative based on previous studies in the literature that have shown both linguistic and social factors to be predictors of /s/ reduction in a variety of dialects. Finally, in Section 2.2 a particular focus will be placed on the phonetic and phonological aspects of /s/ weakening in /st/ consonant clusters in Andalusia Spanish.

To begin, it is important to accurately define the articulatory and acoustic characteristics of the voiceless alveolar fricative /s/ and the aspirated variant [h] that may arise due to weakening. First, in an articulatory sense, a fricative is a consonantal sound produced with a varying degree of airflow restriction in the oral cavity by the narrowing of different articulators (Ladefoged 2006). A further classification is the differentiation between sibilant and non-sibilant fricatives. The distinguishing feature is that for the category of sibilant fricatives, to which /s/ pertains, the obstruction of airflow directs the air against the front upper teeth. The resulting

acoustic signal is occasionally referred to as a hissing sound, “likened to that involved when the wind whistles around a corner” (Ladefoged 2006, 14). In both categories, the fricative may be classified as either voiced, created by regular vibrations of the vocal cords, or voiceless, produced with a lack of vocal cord vibrations. Specifically for the voiceless alveolar fricative /s/, the tongue tip moves towards, but does not come in direct contact with, the alveolar ridge behind the front teeth, creating an obstruction of the air coming through the open vocal folds. The acoustic consequence is a turbulent airflow resulting in a high frequency noise, or frication. A voiceless alveolar fricative can then be identified in a spectrogram by high amplitude frication in the higher frequencies, mostly concentrated around 8,000Hz, and an aperiodic wave in the waveform resulting from the lack of vocal fold vibrations. The process of debuccalization, or reduction of /s/, is a lenition process that occurs when the constriction in the oral cavity is lost and subsequently reduces the consonantal sound to only its laryngeal features (O’Brien 2010). In other words, the sibilant segment loses the oral constriction while maintaining the glottal activity and is realized as aspiration or breathiness. Phonetically, this aspiration is characterized by a period of lower intensity coupled with an aperiodic wave similar to that of the fully realized sibilant /s/. This reduction process equates to the phonetic change of the voiceless alveolar fricative to the voiceless glottal fricative (/s/ → [h]) (Lipski 1999). In conclusion, in an articulatory sense, the characteristics of a fully realized [s] are very similar to those of the weakened variant [h] in that they both maintain the same glottal activity and differ only in the loss of the oral constriction while acoustically, the former is associated with high intensity hissing sound while the latter is perceived as aspiration or breathiness with lower intensity (Terrell 1979).

## 2.1 Previous studies on /s/ weakening

Having discussed the articulatory and acoustic aspects of /s/ and its reduced variant, the focus will now be on previous studies that have investigated possible diachronic models that represent the diffusion of /s/ reduction in different phonological environments. First, in 1978 Terrell began to generate an overview of /s/ reduction by investigating the morphological status of /s/ and its phonological context as two possible factors that may affect debuccalization in Spanish. First, she classifies /s/ into three categories of grammatical morphemes: the plural morpheme (*libro – libros*), the verbal morpheme, for example in the second person singular in the present tense (*estás*), and what she terms the lexical morpheme, where the /s/ has no grammatical bearing (*entonces*). These distinctions were believed to be influential in the conditioning of /s/ reduction from the perspective of the Functionalist Hypothesis, which suggests that /s/ weakening would be blocked in conditions where no other cue is present to aid in the morphological distinction, for example in plural morpheme and verbal morpheme presented above. However, other studies contradict this particular hypothesis with findings that show that the highest percentage of weakened /s/ occurs in inflected words instead of monomorphemic words (Poplack 1980, 1979, Cedergren 1973). Second, Terrell (1978) identifies the importance of the phonological position of the phoneme /s/ and discusses three important contexts: before a pause, before a vowel and before a consonant. Through an analysis of data cited by Navarro Tomás (1948) of a dialect of Spanish spoken in Puerto Rico, she concludes that the usage of aspiration and sibilance is systematic, but she does not propose any phonological rules stating instead that much research is still required to understand the process.

More recently, Méndez Dosuna (1996) and Lipski (1999) expanded Terrell's (1978) discussion of the phonological environments in which /s/ reduction can occur and have used



diachronic accounts of /s/ reduction in a variety of Spanish dialects to explain the phenomenon as a diffusion process in which reduction first begins in syllable final preconsonantal position and then spreads to other phonological contexts in more innovative dialects. Replicated from Méndez Dosuna (1996) and appearing in Brown and Cacoullos (2003), figure 1 below provides a clear model of the steps believed to be involved in the diachronic change of /s/ reduction in Spanish.

**Figure 1:** *Diffusion Pattern of /s/ Reduction in Spanish*<sup>1</sup>

i.) Word medial and word final, syllable final: preconsonantal	s > h / Vs\$C	ex: [lah moh <b>h</b> kas]	<i>las moscas</i>
ii.) Word final: prepausal	s > h / Vs##	ex: [lah mohka <b>h</b> ]	<i>las moscas</i>
iii.) Word final: prevocalic	s > h / Vs##V	ex: [lah alah]	<i>las alas</i>
iv.) Word medial, syllable initial: prevocalic	s > h / VsV	ex: [ke pa <b>h</b> a]	<i>¿qué pasa?</i>
v.) Word initial: prevocalic	s > h / ##sV	ex: [ <b>h</b> i heñor]	<i>Sí señor</i>

More specifically, Lipski (1999) delineates the aforementioned possible variations of /s/ reduction into three stages through which a dialect may progress. First, he claims that “both historically and synchronically, /s/ weakens to [h] in preconsonantal contexts” (Lipski 1999, 198) and that this constitutes the initial stage of /s/ reduction, (i) in figure 1 above. When a dialect is in this stage, /s/ does not reduce in any other contexts other than word medial and word final

<sup>1</sup> From Méndez Dosuna (1996) and Brown and Cacoullos (2003)

preconsonantal positions. Thus, /s/ remains a full sibilant in prepausal positions and before vowels. The second stage of /s/ reduction diffusion, (ii) in figure 1 above, is the emergence of final syllable reduction of /s/ in prepausal positions (henceforth, FSR), in words such as *vamos* [bamoh], while maintaining /s/ as a sibilant in word-final prevocalic positions, such as in the phrase *es así* [es.asi]. Subsequently, more phonologically innovative dialects have progressed further into stage three, represented by (iii) in figure 1 above, and have extended /s/ reduction to the prevocalic final syllable position (henceforth, PFSR). Lipski claims that the progression of a dialect that is already at the FSR stage to the the PFSR stage is not phonetically motivated, but is actually an “analogical extension which results in paradigmatic regularity” (198). In other words, when a dialect employs both FSR and PFSR, all word-final /s/ phonemes are weakened to [h] regardless of surrounding segments. A final stage addressed by Lipski (1999) is a much more recent phenomenon that is considered fairly rare in Spanish, a reduction of /s/ in a word-initial postvocalic position, (v) in figure 1 above.<sup>2</sup> He states that this process is only present in dialects with phonologies that also include PFSR, which implies FSR. These claims have been supported by a multitude of studies that have shown that the overwhelming majority of /s/ reduction occurs in syllable final preconsonantal positions. Terrell (1979) states that one “would expect that the weakening process which produced aspirated phones would occur first in preconsonantal syllable final position since phonetically this is the position in which consonants tend to weaken in all languages, and in particular, throughout the history of the Spanish language, consonants have been subject to weakening processes in syllable final position” (608). A few studies that demonstrate this include Terrell (1979) for Cuban Spanish, Lipski (1983) for Honduran Spanish, Terrell (1986) and Lipski (1994) for Dominican Spanish, Gerfen (2002) for Southern Peninsular

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<sup>2</sup> Lipski (1999) does not make direct reference to Stage IV in this article. However, this stage will be discussed in more detail in regards to Brown and Cacoullos (2002, 2003) in this same section.

varieties, and Bybee (2000) for Cuban and Argentinian Spanish. However, this diffusion process has been recently challenged by the work of Brown and Cacoullos (2002, 2003) who analyzed data from Chihuahua, Mexico where /s/ reduction occurs more frequently in syllable initial word medial position, such as in the word *pasa* [pa.sa] than in syllable final word medial positions, such as in *mosca* [mos.ka]. This is highly relevant to the discussion of /s/ reduction since according to the past models (Lipski 1999, Méndez Dosuna 1996), an /s/ retaining dialect such as that in Mexico should not experience syllable initial word medial /s/ reduction, stage (iv) in figure 1 above, if the dialect has not progressed through the three previous stages. Although Brown and Cacoullos mention that the data should not be used to make representative generalizations due to the limited hours of recordings and small number of speakers, the analysis provides a notable challenge to the proposed unidirectional reduction paradigm of /s/ in Spanish. For this particular study, the authors looked at four phonological contexts in which the sibilant /s/ and its voiced allophone /z/ can be reduced: word initial (*señor*), word medial syllable initially (*dicen*), word medial syllable final (*mismo*), and word final (*una vez*). Their analysis showed that although word final contexts had the highest frequency of /s/ reduction and word initial contexts had the lowest frequency as predicted, the middle two stages showed results incongruent with the model proposed by Méndez Dosuna (1996) and Lipski (1999) since syllable initial word medial, stage four, had a higher frequency than syllable final word medial, stage one. Additionally, stage two did not differ statistically from stage four. The frequency data from this study was then compared to a summary of data collected by Terrell (1977, 1978, 1979) from Argentina and Cuba and it is made clear that although the latter two countries do show an increase in /s/ reduction frequency along the unidirectional preconsonantal > prepausal > prevocalic reduction paradigm for Spanish /s/, the Mexican data does not. Brown and Cacoullos (2003) then

performed a Variable Rule Analysis for each phonological position to better explain the internal linguistic factors conditioning the reduction in each context. For syllable final /s/, it was found that a following liquid consonant conditioned the highest level of /s/ reduction while a following voiceless consonant or a following /s/ predicted the highest levels of /s/ retention. This is in striking contradiction to studies completed on South American and Caribbean dialects where a following obstruent predicted more /s/ weakening (Terrell 1977, Lipski 1984). For syllable initial positions either word medially or word initially, they found that a preceding low vowel or a preceding pause were the most significant predictors of /s/ reduction. To summarize, their findings show that “following phonological environment makes the greatest contribution to final /s/ variation, while syllable initial /s/ looks backward to the preceding phonological environment” (Brown and Cacoullos 2003, 12). Their conclusion is that the continuum of syllable final to syllable initial position proposed by Méndez Dosuna (1996) and supported by Lipski (1999) does not hold up for the data presented from Chihuahua, Mexico. Instead Brown and Cacoullos propose a two-part hypothesis that states that syllable initial /s/ reduction will occur in Spanish dialects where word final /s/ reduction is more frequent before a pause and a vowel than before a consonant, and where overall final /s/ reduction rates are relatively low. In conclusion, despite similarities in the progression of /s/ reduction in many Spanish varieties, evidence has been presented which contradicts a unidirectional account of the phenomenon.

However, the position of the sibilant in a given word is not sufficient information to understand the full breadth of the underlying mechanisms at work in /s/ reduction in Spanish, other linguistic and social factors must also be examined. Commonly investigated linguistic factors for /s/ reduction include the relationship of stress to the segment, morphological category of /s/, type of boundary, and phonetic features of adjacent consonants. In the aforementioned

study by Brown and Cacoullos (2003), it was found that in addition to phonological environment, lexical frequency and relationship of stress to the sibilant were strong indicators of /s/ reduction in syllable final and word medial position, in that words with a higher lexical frequency where the sibilant is in an unstressed syllable patterned with higher rates of /s/ reduction. Lipski (1983) found that /s/ reduction in Honduran Spanish is most frequent in preconsonantal positions but is also possible in intervocalic positions when both adjacent vowels are unstressed. In a study by Kochetov (2011) of Argentinian Spanish, /s/ reduction was more favored by unstressed than stressed syllables, within instead of over a word boundary and when preceding the voiceless dental occlusive /t/ instead of either /p/ or /k/. Alfaraz (2000) investigated the usage of aspiration and deletion of /s/ in Cuban speakers living in Miami and found that aspiration was heavily favored in stressed prevocalic positions while complete deletion was significantly favored in unstressed prepausal positions. In regards to syllable length of words containing /s/, Terrell (1979) found that Cuban Spanish favors a reduction or deletion of /s/ in polysyllabic words instead of monosyllabic words but no difference was found for lexical or inflectional morphological category. Thus, it has been shown that an array of linguistic factors heavily influence the frequency of /s/ weakening.

It is also important to discuss briefly the social factors that have been shown to predict the reduction of /s/. Prominent social factors present in the literature include socioeconomic status, education level, gender, age and the formality of the register. First, a lower socioeconomic status has been shown to pattern with higher degrees of /s/ reduction. A few specific dialects that have been shown to demonstrate this social tendency include Panama City Spanish (Cedergren 1973), Honduran Spanish (Lipski 1983), Chilean Spanish (Cepeda 1995) and Colombian Spanish (Alba 2004). Second, the level of education of a speaker is known to affect the degree of /s/

weakening with less educated speakers producing higher degrees of /s/ reduction. This finding has been documented for Dominican Spanish (Alba 1982), for Cuban Spanish (Uber 1989), for Salvadorian Spanish (Taler 1997), for Colombian Spanish (Lafford 1986). Thirdly, it has been shown in Andalusia that women tend to maintain the fully realized sibilant as a plural morpheme more than men (Uruburu Bidaurrázaga 1990) while Lafford (1986) and Cepeda (1995) found that it is men that typically reduce /s/ in Colombian Spanish and Chilean Spanish, respectively. However, yet many other studies have found that gender is not a reliable predictor of /s/ reduction in Spanish (see Alfaraz 2000 for a summary). Next, age of the speaker has been shown to be an inconsistent social factor. Although many studies suggest that /s/ reduction is a change in progress and as a result is more frequent in younger age groups (Lipski 1984, Lynch 2009), Lafford (1986) found younger generations and older generations pattern similarly in regards to rates of /s/ reduction in Colombian Spanish while Alfaraz (2000) found that older speakers of Cuban Spanish produced reduced /s/ variants with more frequency than younger generations. Finally, /s/ reduction is often more common in less formal speech registers than in more formal ones. Lafford (1986) found that as the formality of the experimental task increased, so did the number of fully realized sibilants. Many studies suggests that any type of /s/ reduction, since having been shown to be associated with lower socioeconomic status and lower education level, is in turn associated with lower prestige than the maintenance of the fully realized sibilant (Trudgill 1972). However, many other studies have shown that the aspirated variant of /s/ is considered a neutral allophone of the fully produced sibilant while full deletion of the segment maintains a strong social stigmatization. This has been attested for the Spanish of Buenos Aires (Lynch 2009), of Chilean Spanish (Valdivieso and Magaña 1991) and in Seville Spanish (Carbonero 1982). In conclusion, it appears that purely social factors provide inconsistent

information on the presence or absence of /s/ reduction in Spanish dialects around the world and should be taken into account concomitantly with linguistic factors.

Next, after discussing the possible phonological environments and their effects on the likelihood of /s/ weakening in different Spanish dialects, a more careful analysis of the correlates of /s/ reduction in the region of Andalusia will be presented. To begin, a great deal of literature attests to the fact that no other dialect zone in Spain has received more attention than Andalusia (Carbonero 1982, Lamínquiz 1982, among others). Lipski describes the dialect by saying that “the pronunciation of Andalusian Spanish is so unmistakable as to constitute the most widely-employed dialect stereotype in literature and popular culture” (Lipski n.d., 1). In an unpublished manuscript, Lipski provides a detailed summary of this particular dialect and he concludes that despite having many salient phonetic and phonological characteristics, the most relevant is that of the reduction of /s/ in both syllable final and word final positions in virtually all areas of the region. More specifically, Lipski states that the phenomenon of /s/ weakening is almost categorical in the region, most prominently in preconsonantal positions. Also, when /s/ is reduced in prevocalic position, the aspiration tends to remain and is typically resyllabified into the onset of the following syllable. One interesting phonological environment that seems to act as an exception is that of word final /s/ in prevocalic position when the following syllable contains an [h], such as in *los hijos* [losího(h)]. Lipski says that the /s/ in this context is either maintained as a fully realized sibilant or is elided completely in order to avoid a [...hVh...] sequence, such as *los hijos* being pronounced as [lohiho(h)]. More recently, an influential article by Chip Gerfen (2002) has provided insight into the /s/ reduction phenomenon in the Eastern region of Andalusia where aspiration occurs word finally and word internally in preconsonantal position and /s/ is only fully realized in intervocalic positions. Gerfen states that a salient

property of EAS is a lack of contrast for obstruents in coda position. That is to say, a typically contrastive obstruent in coda position in Standard Spanish will be weakened and will lose contrastive features in coda position in EAS. Of particular interest here is the effect of this dialectal property when /s/ is present in a non-contrastive coda position. Gerfen shows that when /s/ appears in this vulnerable coda position it is deleted, normally with a concomitant aspiration and a lengthening of the preceding vowel, resulting in the gemination of the following consonant, such as in the word *bosque* [bos.ke] > [bok.ke]. In order to analyze quantitative data, he conducted a production study with 10 speakers of the EAS dialect. His goal was to investigate the correlation of the duration of the closure for the following occlusive, the length of the preceding vowel and, if applicable, the combined duration of the aspiration of the reduced /s/ and the preceding vowel segment. It seems noteworthy here to mention that the Spanish spoken in Andalusia is typically described as being of low prestige in relation to those dialects spoken in other regions of Spain. Thus, an orthographic study presents some particular challenges. Gerfen claims to have overcome these methodological concerns by embedding the target words in an informal carrier sentence consisting of typical and informal lexical items native to the region. His target words consisted of both [CVCV] and [CVsCV] syllable structures, a methodological decision that allowed for an investigation of the phonetic realizations of words with and without an underlying, orthographic /s/. He discarded any tokens that contained a medial sibilant as his focus was the realization of syllables containing a weakened variant of /s/. His results showed that all three measurements, duration of the closure for the following occlusive, length of the preceding vowel and the combined duration of the aspiration of the reduced /s/ and the preceding vowel segment proved to be reliable predictors of /s/ in EAS. However, he does note that the preceding vowel and the aspirated segment needed to be combined in order to produce a



statistically significant correlation with /s/. This may possibly arise from the difficulty of segmenting accurately the aspirated segment from the vowel. Nevertheless, these findings show that mere aspiration of the sibilant is not the only correlate with /s/ reduction. Instead the compensatory lengthening of both the preceding vowel and the following occlusive are also reliable predictors. Taking the three groups of measurements individually, Gerfen found that closure duration of the following occlusive acts as the most robust cue of an underlying /s/ in coda position in the EAS variety of Spanish, which corroborates the distinguishing characteristic of consonant germination mentioned previously. However, on a whole, he found a much more interesting finding in that the entire vowel + consonant segment surrounding the underlying /s/ is actually the best indicator. That is to say, vowel and consonant lengthening are not independent of each other, but in fact are working together in a trade-off relationship: as one increases in duration, the other decreases. Other studies have also found compensatory lengthening of preceding vowels to be a linguistic correlate of /s/ reduction in Andalusia (Hualde 1989, Lipski n.d.).

A final phenomenon associated with /s/ weakening in Andalusia, more specifically in EAS, is the opening of vowels preceding a weakened /s/ and subsequent vowel harmony triggered by this opening of vowels (Lipski, n.d.). Discussed by Hualde and Sanders (1995), the aspiration or deletion of an underlying /s/ in EAS can cause preceding mid and low vowels to be more open and lax. An example would be the singular form of *mono* [mono] differing in vowel quality from the plural form *monos* [mɔnɔ<sup>(h)</sup>] in that the mid vowel preceding the aspirated or deleted sibilant opens as a result of the /s/ reduction. Subsequently, this vowel opening then extends to the other preceding vowels in the prosodic word. This vowel harmony phenomenon

has been shown to occur in stressed and unstressed phonological contexts and to function as a reliable predictor of reduced underlying sibilants in certain regions of Andalusia (Kaplan 2012).

In conclusion, the reduction of /s/ in Spanish is a widely researched, complex and pervasive process conditioned by a variety of factors, both linguistic and social in nature, that can be found in many dialects. Of particular note, Andalusian Spanish has received a great deal of scholarly attention for being such a phonologically innovative dialect. Here, this particular variety has been discussed in regards to the social implications and linguistic phenomena associated with /s/ reduction. In the following section, this dialect will be discussed in regards to a specific phenomenon occurring as a result of /s/ reduction, the postaspiration of voice occlusive consonants.

## 2.2 Previous studies on /st/ consonant clusters in Andalusia, Spain

Within the past 10 years, only a handful of articles have been published on /s/ reduction in Seville, Spain, a current phenomenon resulting in postaspiration of the voiceless occlusive /t/. Each researcher has stated clearly that much work is left to be done. One of the first studies conducted was Corral (2007) in which a sociolinguistic approach was employed to investigate the change in pronunciation of /st/ clusters by Andalusian speakers from the aspirated variant [ht] to the innovative dental-alveolar affricate [t<sup>s</sup>]. Corral's included residents of Seville and of the nearby rural town of Antequera who completed a sentence reading task, a picture description task and a word list reading task. Although the analysis was entirely impressionistic, the distribution of possible variants in word internal /st/ clusters showed that the variant [t<sup>s</sup>] is much more prominent in informal speech and remains contained to the metropolitan center of Seville and has not extended past the city limits to the rural towns. Through the use of Chi-squared tests, Corral shows that the rate of production of the [t<sup>s</sup>] variant was significantly higher for those under the age of 25 and those with a secondary level of education, while finding no significant results for differences in gender. In a final section of his article, he discusses the participants' level of interaction with cultural and news programs on the radio. His findings show that in both cities, those participants who listened to the radio at least once a week had the highest percentages of [t<sup>s</sup>] realizations. Interestingly, in Seville the next highest concentration of [t<sup>s</sup>] productions were by those participants that listened to the radio with more frequency, while the next highest concentration of [t<sup>s</sup>] productions in Antiquera were by those participants that listened to the radio with less frequency. As a result, Corral concludes that this sound change is both recent and currently evolving in both areas; yet it is being proliferated by prestige in Seville while the opposite is occurring in the rural town of Antiquera. Thus, Corral's impressionistic

analysis provides exploratory insight into the evolving phenomenon, yet a more precise phonetic approach is required to better understand the nature of this postaspiration phenomenon resulting in either the aspirated dental occlusive [t<sup>h</sup>] or the dental-alveolar affricate [t<sup>s</sup>]. Also, Corral's study merely investigates the social factors conditioning the distension of this innovative production, thus leaving the linguistic, internal factors unexplored.

More insight into this phenomenon is presented in a detailed study by Ruch (2008) in which she asserts that there exists up to eight different variations of pre and postaspiration currently being produced in the city center of Seville. The purpose of her study is two-fold: to describe in phonetic terms the innovative /t<sup>s</sup>/ variant and to examine the social and linguistic factors that condition its usage. First, she provides an analysis showing that the postaspirated variants [t<sup>h</sup>] and [t<sup>s</sup>] are phonetically distinct and that the latter should be classified as an affricate. Although she clarifies that the distinction between aspiration and affrication is not always clear, she used several factors to distinguish them. These included the duration of VOT, the relation between the duration of VOT and the duration of the segment, the Center of Gravity as an indicator of place of articulation, and the maximum frequency of the frication following the release of the voiceless consonants. She states that high Center of Gravity values are consistent with a fronted place of articulation, and a maximum frequency values over 10-kHz are consistent with affricates. These two factors together were the most concrete indicators used in determining the affricate variant /t<sup>s</sup>/. Although this distinction lies outside the scope of the current study, the addition of her phonetic descriptions of [t<sup>h</sup>] and [t<sup>s</sup>] to the field are vital for a deeper understanding of the phenomenon. Next, through extensive collection of data consisting of informal speech obtained through sociolinguistic interviews, and more formal speech gathered through a sentence reading task, Ruch (2008) provides statistically significant results

demonstrating that a large percentage of the productions of postaspiration in Seville can be categorized as affricates. Secondly, she investigates the external and internal factors conditioning this affricate.<sup>3</sup> Her work corroborates that of previous literature (Corral 2007, Torreira 2007a) in regards to social factors in showing that the affricated postaspiration is most commonly produced by those of younger generations with higher levels of education, with gender not being a reliable predictor. As for linguistic factors, she found that an /st/ cluster is more likely to be produced as the affricate variant in word internal contexts and in an intervocalic position where the preceding vowel is an /i/ such as in the word *visto* ‘seen’ or an /e/ such as in the word *destino* ‘destiny’, instead of following a nasal consonant or preceding a rhotic in a words such as *instante* ‘instant’ and *postre* ‘dessert’. She also investigated the effect of lexical frequency and found that the higher the frequency of the word containing the /st/ cluster, the higher the probability of a production of the affricate variant. Thus, this final and most recent study has supplied the linguistics field with the largest quantity of /st/ productions, as well as clear phonetic categorizations of the many possible variants: however, more analysis of the conditioning phonological contexts is required in order to better understand the mechanisms behind this sound change and determine if it has spread to the other voiceless occlusives, /p/ and /k/.

Then, Torreira (2007a) conducted a study that investigated the phonetic correlates of this innovative /s/ aspiration in the dialect of Seville in comparison with dialects of Northern Spain. His experiment consisted of a sentence reading task that contained disyllabic words containing one of the three voiceless occlusives, /p, t, k/ in word medial, syllable initial position; where the preceding coda was either empty, contained /s/ or contained /l/. Additionally, he investigated the impact of the preceding vowel, either /a/ or /i/. For example, /papa/ “potato”, /pata/ “leg” and

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<sup>3</sup> Ruch (2008) analyses only the conditioning factors for the affricated variant [t<sup>s</sup>], not for any other postaspirated variants, such as [t<sup>h</sup>].

/paka/ “proper noun” were used to investigate different types of occlusives. In conjunction with these, examples like /kako/ “burglar”, /kalko/ “calque” and /kasko/ “helmet” were used to investigate the effect of the different types of the coda in the first syllable. It is important to note that as the purpose of this study was to investigate both preaspiration and postaspiration in this dialect and any tokens that contained a fully realized sibilant were discarded. Accordingly, any discussion of /s/ from this study refers to the underlying /s/ being realized as its aspirated variant [h]. His findings show that postaspiration of the three voiceless occlusives /p, t, k/ is conditioned only in the context of a consonant cluster containing an /s/ in the coda position. That is to say, occlusives that were preceded by an empty coda position or one that contained an /l/ were not produced with significant levels of postaspiration. Also, through the use of one-way ANOVAs, Torreira found a statistically significant difference in the duration of both stop closure durations and VOT durations, which correlated directly with postaspiration duration, in the Western Andalusian dialect in comparison with those of Northern Castilian, that were in agreement with those found by Gerfen (2002) for EAS. Both the duration of the stop closure and the combined duration of the preceding vowel and aspiration were significantly longer when a word contained an /s/ in the coda position than in any other type of coda. However, the effect of vowel lengthening must be considered carefully as Torreira employed the methodology of Gerfen (2002) in which the duration of the entire rhyme was used instead of simply the duration of the vowel. That is to say, words containing only one segment in the rhyme, for example /kako/, were compared to those with two segments, for example /kalko/ and /kasko/. As a result, it seems obvious that those words with two segments in the rhyme were correlated with the longer rhyme durations and that it is possible that the length of the vowel duration may not be an effect of the specific consonants in the coda position but merely their presence. In the second section of this

study, Torreira investigates the duration of postaspiration of the voiceless occlusive /t/ in spontaneous speech data. Using eight interviews from the Andalusian television channel Canal Sur, four by Western Andalusian speakers and four by Eastern Andalusian speakers<sup>4</sup>, the duration of postaspiration for the voiceless dental occlusive /t/ of both /Vt/ and /Vst/ sequences was measured and compared. It is important to note that in this section of his study, no linguistic factors were taken into account and the only differentiation made was between Western and Eastern Andalusian speakers. His results showed statistically significant increases in duration of the occlusive /t/ for Western Andalusian speakers when preceded by an orthographic /s/. More specifically, the two speakers from Seville produced the longest durations of postaspiration. However, although the contexts were defined as either /Vt/ or /Vst/, the production of the sibilant, as either reduced or maintained, in the second context was not discussed. Although the investigation of spontaneous speech is important since the degree of formality has shown to impact the quality and quantity of postaspiration (Corral 2007, Ruch 2008) the role of internal factors and linguistic correlates should not be discounted or eliminated. Following this study, Torreira (2007b) conducted a similar investigation that analyzed these same /s/ + voiceless occlusive clusters in Western Andalusia through a comparison to other aspirating dialects of Argentina and Puerto Rico. In all three dialects, Torreira states that /s/ aspiration is manifested most commonly in word-internal preconsonantal positions; word-final, preconsonantal positions; and prepausal positions. Torreira continues by saying that dialectal differences in /s/ aspiration exist only in the preconsonantal position and that it depends on the nature of the consonant. Thus, Torreira tests this idea by using the same methodology as in his (2007a) article, a word reading task, discussed above. For the speakers of Western Andalusian Spanish, /sC/ clusters,

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<sup>4</sup> Western Andalusian speakers being from either Seville or Huelva and Eastern Andalusian speakers being from either Granada or Jaén.

where the consonant was a voiceless occlusive, resulted in longer postaspiration and short or nonexistent preaspiration. However, unlike in Western Andalusian Spanish, /s/ aspiration in preconsonantal context consisting of a voiceless occlusive manifests differently in both the Argentinian and Puerto Rican dialects in that there is consistent preaspiration and little to no postaspiration. A series of repeated-measures ANOVAs determined that Western Andalusian Spanish exhibits statistically significantly longer VOT durations for all three voiceless occlusives following an orthographic /s/. Also, preaspiration of the sibilant was significantly shorter than for both the Argentinean dialect and the Puerto Rican dialect.

Two more recent studies that have investigated this innovative speech phenomenon in Seville, Spain have employed the theoretical framework of Articulatory Phonology, developed by Catherine Browman and Louis Goldstein (1986, 1989, 1992), in order to better explain their findings. The basic tenets of this theoretical model will be addressed first and then the two relevant studies will be explored in better detail. To begin, Articulatory Phonology is a theoretical model that relates the discrete phonemes of phonological representations and the dynamic physicality of natural speech in phonetic realizations. The fundamental aspect of this theory is the use of articulatory movements, known as gestures, as the most basic units of phonological contrast. Then, these gestures are aligned into spatiotemporal patterns that allow for the representation of the articulatory mechanisms employed throughout the production of speech sounds. Thus, a discrete phoneme, for example the voiceless alveolar sibilant /s/, can be broken down in two independent gestures: an oral constriction formed by the contact of the tongue tip articulator and alveolar ridge and an opening of the glottis that allows free passage of air through the oral cavity. Both of these gestures are then aligned temporally so that their combination is able to explain the articulatory production and acoustic consequences of the sibilant /s/. The



analysis of speech sounds as individual articulatory gestures that are capable of beginning and ending in different places on the temporal spectrum permitting for different degrees of overlap, allows for a clear representation of coarticulation of adjacent speech sounds. This model will be further discussed in Section 6 of this study.

To continue, Torreira (2012) investigated the effect of speech rate and stress pattern on the duration of VOT as well as the relationship between closure duration, preaspiration and VOT duration. He hypothesized that if the duration of VOT is “acting as an acoustic cue in a class of aspirated stops, it should be longer at slow speech rate and in stressed positions” whereas if it is a product of coarticulatory compensation then the VOT should be longer in unstressed syllables and in fast speech rates (Torreira 2012, 58). In other words, if VOT duration is a product of coarticulation, the increase of speech rate should increase the overlap of the articulatory gestures involved, resulting in a longer VOT duration. However, if the VOT duration is an additional part of an aspirated voiceless occlusive and not merely a result of coarticulation, it will be produced with longer duration in slow speech rates when all gestures are not forced to overlap on the temporal spectrum. He tested these hypotheses by having three native speakers of Western Andalusian Spanish read carrier sentences containing disyllabic verbs whose infinitive form ends in either *-aspar*, *-astar* or *-ascar*. Different conjugations of the verbs allowed for both pretonic and posttonic stress placement and speech rate was manipulated by the speed at which the carrier sentences were presented. Due to the tendency of Western Andalusian Spanish speakers to aspirate /s/ in a word medial, preconsonantal position, the few tokens in which a fully realized sibilant was present were discarded. Torreira found that neither speech rate nor stress position were significant factors in predicting the duration of VOT. In fact, unstressed positions displayed slightly longer VOT durations than that of stressed positions. However, trade-offs were found

between postaspiration and preaspiration plus closure durations. Thus, on the basis of the trade-off resulting from coarticulation, Torreira concluded that “long VOT in Western Andalusian Spanish voiceless stops preceded by aspirated /s/ does not act as an acoustic cue of the stop consonant” (Torreira 2012, 58). Yet, the data did reveal a significant negative correlation between VOT duration and the sum of both preaspiration and closure duration. According to Torreira, this negative correlation must then be the result of coarticulatory compensation. That is to say that aspirated /s/ + voiceless stop clusters in Western Andalusian Spanish are produced with significant articulatory overlap of the glottal frication from the aspirated /h/ and the following oral constriction of the voiceless stop.

In a similar fashion, Parrell (2011) provided a theoretical description of this postaspiration phenomenon in Andalusia with his study that investigated the effect of increased speech rate on the production of pre- and postaspiration. In his study, the native-born Sevillian participants read sentences containing one target word, *pastándola* “grazing-it”, in which an /st/ consonant cluster is in a word medial position with posttonic stress, while simultaneously hearing the fluctuating rate of a bell. Unlike in Torreira (2012), Parrell did find a significant correlation between speech rate and postaspiration in that as speech rate increased, so did postaspiration of the voiceless occlusive /t/. In accordance with the coarticulatory compensation model discussed by Torreira (2012), Parrell fits his findings in the theoretical model of Articulatory Phonology. He concludes that preaspiration and postaspiration are representative of two types of articulatory gestural organizations. More specifically, preaspiration results from a glottal gesture existing in an anti-phase relationship with the occlusive gestures. This means that the glottal gesture responsible for the aspiration begins before the start of the oral gestures required in the production of the voiceless consonants /p, t, k/. On the other hand, postaspiration

represents the same glottal gesture in an in-phase relationship with the occlusive oral gestures. This implies that the glottal gesture associated with the aspiration and the oral gestures associated with the voiceless consonant begin simultaneously. The sequential timing of movements in an anti-phase organization (preaspiration) has been shown to be less stable than the synchronized timing of in-phase organizations (postaspiration) (Kelso 1984). That is to say, according to these articles, it is more likely that the aspiration will begin at the same time as the following voiceless consonant, resulting in a longer postaspiration instead of preaspiration. Thus, Parrell predicts a high degree of within subject variation since Spanish permits both types of gestural organizations. However, once a speaker has established the use of the in-phase, or simultaneous, organization, Parrell predicts they will not reverse the order of change and revert back to the unstable anti-phase, or sequential, organization. More specifically to this study, once a speaker adopts the gestural organization for postaspiration, it is very unlikely that they will return to the more unstable gestural organization for preaspiration. The results from Parrell's (2011) study on speech rate show that when a speaker's production rate is increased, most speakers fluctuate between these two gestural phase organizations before committing to the in-phase relationship. Interestingly, Parrell notes that there is still no evidence as to why this change is occurring only in Western Andalusian Spanish, specifically in the urban center of Seville.

In conclusion, although relatively few studies have been conducted on postaspiration of /s/ + voiceless occlusive clusters in Andalusia, they have shown that a variety of social and linguistic factors are capable of predicting the postaspiration of /st/ clusters in Seville Spanish. Socially, longer durations of postaspiration have been shown to be more prevalent among younger speakers while results for education level have been inconsistent and gender has been proven to be an insignificant factor. Linguistically, word internal and unstressed positions have

been documented as predicting longer postaspiration. Also, the duration of preaspiration and stop closure have been shown to correlate negatively with VOT durations suggesting a trade-off of articulatory gestures.

### 3. Research objectives and hypotheses

In light of the aforementioned previous research, the objectives for this study are three-fold. First, to investigate the postaspiration of an underlying alveolar sibilant /s/ when followed by the voiceless dental occlusive /t/ and its possible extension to the voiceless bilabial occlusive /p/ and the voiceless velar occlusive /k/ in the city of Seville, Spain. Second, to identify and document the social and linguistic factors conditioning postaspiration in these voiceless occlusive contexts. Third, following the methodology of Parrell (2011) and Torreira (2012), to analyze this sound change and its contributing factors from the perspective of Articulatory Phonology (Brown and Goldstein 1992). To begin, the hypotheses and justifications, on the basis of past investigations, for this current study are presented below.

1. Younger speakers will exhibit higher rates of postaspiration than that of older speakers. As seen in all of the previous studies, the younger generation has shown consistently higher rates of postaspiration than that of older generations.<sup>5</sup>
2. Speakers with a higher level of education will display higher rates of postaspiration than speakers with a lower level of education. In Corral (2007) the highest percentages of postaspiration were documented for those speakers who completed a secondary level of formal education, with relatively low percentages for those with only primary education and those with university level instruction. However, Ruch (2008) found a positive correlation between education and postaspiration so that the highest level of education, defined as completion of university, indicated a higher rate of postaspiration. Since these two studies diverge with opposing findings, this current study will aim at exploring the impact of education on postaspiration.

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<sup>5</sup> In Ruch (2008), the highest frequency of the affricate [tʰ] was found to be for younger speakers. No data is presented about age effects for other postaspirated variants.

3. Postaspiration will be more frequent in /s/ clusters containing a voiceless dental occlusive than those containing a bilabial or velar occlusive. If this hypothesis is shown to be correct, it will expand the findings of Torreira (2007a), in which occlusive type was a secondary factor and not examined statistically.
4. Postaspiration will occur more frequently and have a longer duration in an /s/ + voiceless occlusive cluster located word internally, in contrast with over word boundaries for all occlusive types. The confirmation of this hypothesis will provide stronger evidence for this indicator that was found significant in the work by Ruch (2008) for the dental occlusive /t/.
5. Postaspiration will be found more often when the voiceless stop is part of an unstressed syllable. In conjunction with the findings of Torreira (2012), although they were not statistically significant, it was found that longer durations of VOT were found in unstressed rather than in stressed syllables. Following the work of Parrell (2011), since the duration of unstressed syllables tends to be shorter than stressed syllables, it is hypothesized that a greater amount of overlap of articulatory gestures may result in longer postaspiration in these shorter, unstressed syllables.
6. Complete elision of the /s/ will favor the postaspiration of the voiceless occlusive. As discussed from Torreira (2012), the duration of preaspiration and stop closure duration acted as a predictor for VOT duration as they were found to be negatively correlated. Thus, if the shorter the duration of the preaspiration and the stop closure, the longer the VOT duration, it is hypothesized here that a complete elision of the fricative will also result in longer VOT durations.

## 4. Methodology

In order to empirically investigate the aforementioned research questions and hypotheses, an experiment was designed in which native Spanish speakers from the city of Seville, Spain were recruited to participate in a sentence reading task. In this section, first the demographics of the participants will be discussed, followed by an explanation the development of the stimuli and the experimental procedure and finally the parameters used for the acoustic analysis are presented.

### 4.1. *Participants*

This study consists of the recorded speech of 26 speakers from Seville, Spain that have lived and worked in the metropolitan area for their entire lives. The recruiting for this study was conducted in such a way as to have an even number of speakers across age group, gender and educational level. A total number of 26 speakers were used for this analysis. The mean age of the participants is 34.1 years, ranging from 19 to 66 years of age. For the sake of the analysis, the participants were categorized into three age groups, 19-29, 30-40 and 41+, in order to better investigate the possible influence of belonging to a particular generation. The gender of the participants was equally divided, with 13 males and 13 females. The education level categories chosen were completion of high school or trade school, a university education (minimum two years completed) or the completion of an advanced degree, such as a Doctorate or a Masters. Table 1 below provides a more detailed outline of the age, gender and educational level for each speaker.

**Table 1:** *Participant Information*

	<b>SPEAKER</b>	<b>AGE GROUP</b>	<b>GENDER</b>	<b>EDUCATION LEVEL</b>
1	MCMM	Young	Female	MA/PhD
2	MRP	Young	Female	MA/PhD
3	SVF	Young	Female	Trade School
4	MVR	Young	Female	University
5	IRM	Young	Female	University
6	RS	Young	Male	Trade School
7	EGM	Young	Male	Trade School
8	JGS	Young	Male	Trade School
9	EGR	Young	Male	University
10	DLH	Young	Male	University
11	CSR	Middle	Female	MA/PhD
12	EJM	Middle	Female	MA/PhD
13	ML	Middle	Female	Trade School
14	FGL	Middle	Female	Trade School
15	ND	Middle	Female	Trade School
16	MVC	Middle	Female	University
17	JJ	Middle	Male	Trade School
18	ANT	Middle	Male	Trade School
19	CCC	Old	Female	MA/PhD
20	JLPB	Old	Male	MA/PhD
21	JMG	Old	Male	MA/PhD
22	FSB	Old	Male	MA/PhD
23	JA	Old	Male	Trade School
24	ALDESA	Old	Male	Trade School
25	HL	Old	Male	University
26	JMD	Old	Male	University



## 4.2 *Stimuli and procedure*

The participants for this research were informed that they were part of a study about different dialectal patterns found in Spain. Each speaker completed a sentence reading task in which the stimuli were shown to them using presentation software on a laptop computer in a quiet location. The independent linguistic factors manipulated in this study include the place of articulation of the following occlusive, the position of the relevant consonant cluster, and the position of lexical stress in relation to the /s/. Thus, the sentences used in this task contained the target consonant clusters /sp/, /st/ and /sk/ in word medial position and across word boundaries either preceded by, followed by or not in the presence of a stressed vowel. The relevant clusters were consistently flanked by either low or mid vowels. Examples of each category of stimuli are presented below in Table 2. Each target word or phrase was placed in the middle of a simple, semantically appropriate Spanish sentence. They were purposely not placed at utterance initial or utterance final positions in order to minimize any possible effect of their positions. The sentences were presented in a random order that guaranteed no sequence of identical stimuli. There were a total of 30 sentences and each was repeated 3 times for a total of 90 stimuli per speaker. Accordingly, 26 speakers with 90 stimuli results in 2,340 possible tokens. 107 tokens were not included in the analysis due to disruptions during the recording, distortions in the spectrogram due to interference from other technological devices, accidental mispronunciations or unnatural pauses during production of the target word. Thus, the final analysis was completed with 2,233 tokens. Table 2 below presents the different phonological contexts according to which the stimuli were categorized, including place of articulation, type of word boundary and position of prosodic stress in relation to the orthographic /s/. Additionally, an example of each combination is provided with a phonetic transcription and an English translation.

**Table 2:** *Sample Stimuli*<sup>6</sup>

<b>Phonological context:</b>	<b>Sample stimuli</b>		
	<b>/sp/</b>	<b>/st/</b>	<b>/sk/</b>
<b>Word Internal Boundary Preceding Stress</b>	<i>déspota</i> ‘despot’ [ˈdes.po.ta]	<i>costa</i> ‘coast’ [ˈkos.ta]	<i>mosca</i> ‘fly’ [ˈmos.ka]
<b>Word Internal Boundary Following Stress</b>	<i>esposo</i> ‘wife’ [es.ˈpo.sa]	<i>postal</i> ‘postcard’ [pos.ˈtal]	<i>roscón</i> ‘pastry’ [ros.ˈkon]
<b>Over Word Boundary Following Stress</b>	<i>los perros</i> ‘the dogs’ [los#ˈpe.ros]	<i>las tapas</i> ‘the tapas’ [las#ˈta.pas]	<i>las casas</i> ‘the houses’ [las#ˈka.sas]
<b>Over Word Boundary No stressed vowel preceding or following</b>	<i>los perrazos</i> ‘the big dogs’ [los#pe.ˈra.θos]	<i>las tapitas</i> ‘the small tapas’ [las#ta.ˈpi.tas]	<i>las casetas</i> ‘the tents’ [las#ka.ˈse.tas]

To summarize, the independent variables being manipulated in this study are as follows:

- Age (Groups: 18-29, 30-40, 41+)
- Gender (male vs. female)
- Education level (trade school vs. university vs. higher education)
- Place of articulation of the voiceless occlusive after the sibilant (p vs. t vs. k)
- Position of the cluster (word internal vs. over word boundary)
- Position of the stressed vowel (before vs. after the cluster vs. a different syllable)

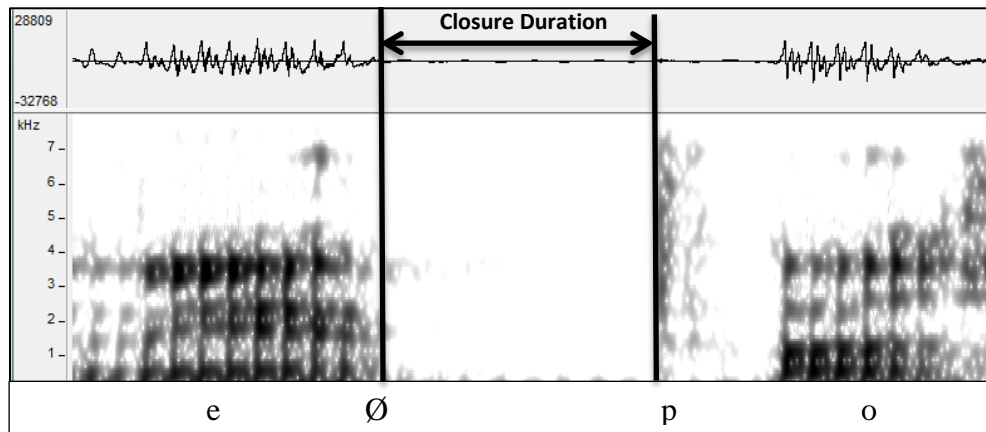
#### 4.3 Acoustic analysis

All recordings were made using a head-mounted microphone and digitally recorded onto a Toshiba laptop at a sampling rate of 2200Hz, 64bit. Each stimulus was analyzed using the speech analysis software Wavesurfer. The three measurements taken from each consonant cluster include: the duration of the preceding vowel, the duration of the sibilant or of the preaspiration if present, the duration of the closure for the following occlusive and the duration of the voice onset time (VOT) of the occlusive. First, the onset of the preceding vowel was measured at the first glottal pulse after the release of the word initial occlusive and the offset was marked at a sharp decrease in the intensity of the second formant, as well as the ending of the voicing bar.

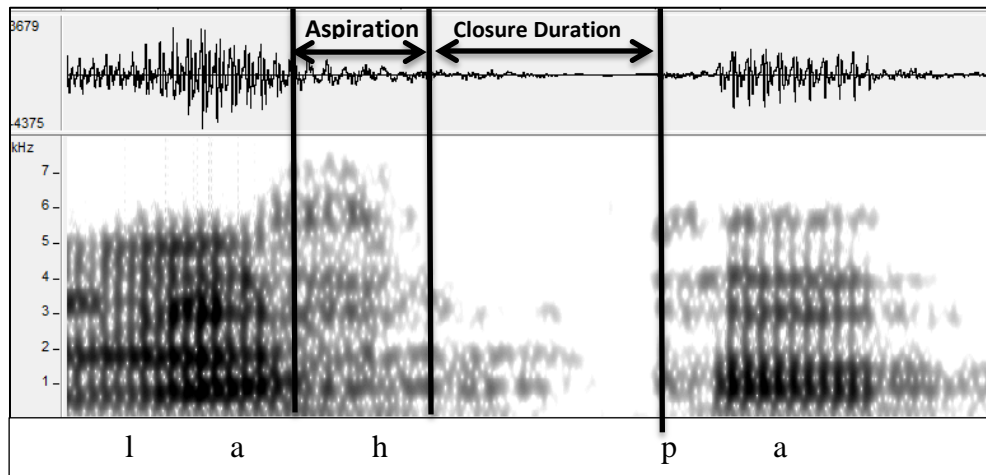
<sup>6</sup> A complete list of the stimuli is attached in Appendix 1

Next, the segment preceding the vowel was categorized as either being elided, aspirated or produced as a full sibilant. The orthographic fricative was classified as elided when there was an abrupt drop of energy of the second formant of the preceding vowel and no clear frication was present. An example of an elided /s/ is presented in Figure 1. The fricative was classified as being aspirated when a clear presence of energy with low intensity was found at the 4,000-5,000Hz range in conjunction with aperiodic noise in the waveform. An example of a preaspirated token is shown below in Figure 2. The onset was marked at the clear decrease of energy in the second formant of the preceding vowel, which if not clear was then marked by the abrupt ending of the voicing bar, and the offset was marked at the decrease of energy in the 4,000-5,000Hz range. In several tokens, spurious noise was found in the higher frequencies similar to those of the aspirated tokens. However, based on the author's acoustic impression, it was decided that these tokens were not aspirated and thus categorized as elided. Finally, a fully produced sibilant was characterized by a prominent presence of frication in the 5,000-9,000Hz range. The onset of the sibilant was delimited by the decrease in energy of the second formant of the preceding vowel and the offset was marked according to the decrease in intensity in the 5,000-9,000Hz range, as can be seen in Figure 3. As seen in a comparison of Figures 2 and 3, the most prominent distinguishing factor between the aspirated /s/ and the fully realized /s/ was the degree of intensity in the higher frequencies. Subsequently, each token was categorically labeled and coded as having an elided, aspirated or fully realized sibilant. This grouping was later analyzed as a separate independent variable conditioning postaspiration.

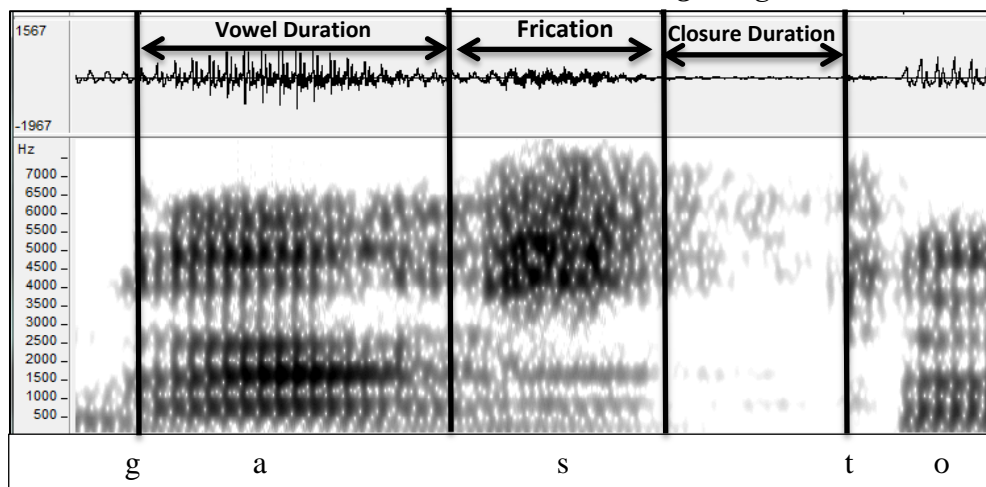
**Figure 1:** *An Elided Sibilant in the Sentence, “Hablo con mi esposo cada día”.<sup>7</sup>*



**Figure 2:** *An Aspirated Sibilant Produced in the Sentence, “Compro las papas allí”.<sup>8</sup>*



**Figure 3:** *A Full Sibilant Produced in the Sentence, “Es un gasto grande”.<sup>9</sup>*



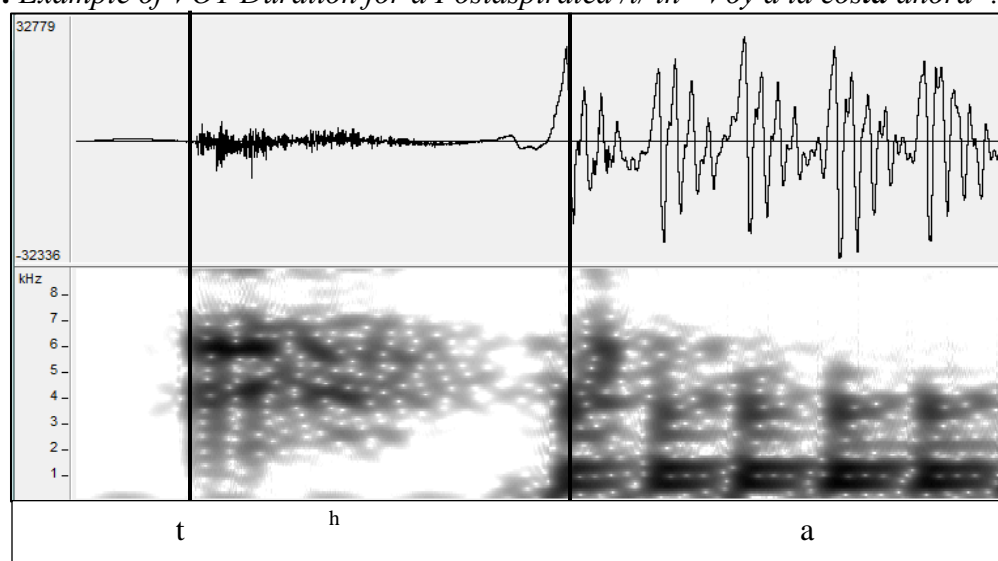
<sup>7</sup> Speaker RS, token Hablo\_con\_mi\_esposo\_cada\_día.22

<sup>8</sup> Speaker JA, token Compro\_las\_papas\_allí.41

<sup>9</sup> Speaker ALDESA, token Es\_un\_gasto\_grande.4

The measurement guidelines followed for delimiting the duration of the closure for the voiceless consonant were determined by the quality of the sibilant segment. If the sibilant was completely elided, the onset of the closure for the consonant was marked at the decrease of energy from the second formant of the preceding vowel, as can be seen in Figure 1. If the sibilant was aspirated, the onset of closure was determined by the absence of noise in the 4,000-5,000Hz range, as can be seen in Figure 2, and if the sibilant was fully produced, the onset was determined by the abrupt decrease in intensity in the 4,000-7,000Hz range, as can be seen in Figure 3. The offset of the closure was marked at either the beginning of the explosion bar for the release of the consonant or at the beginning of voicing bar for the following vowel if no release was present, as seen in Figures 1, 2 and 3. Finally, the starting point for the duration of the VOT for the voiceless consonant was marked at the beginning of the explosion bar and the endpoint was marked at the downward zero-crossing of the first full period of the following vowel. These criteria for VOT measurements are shown below in figure 4.

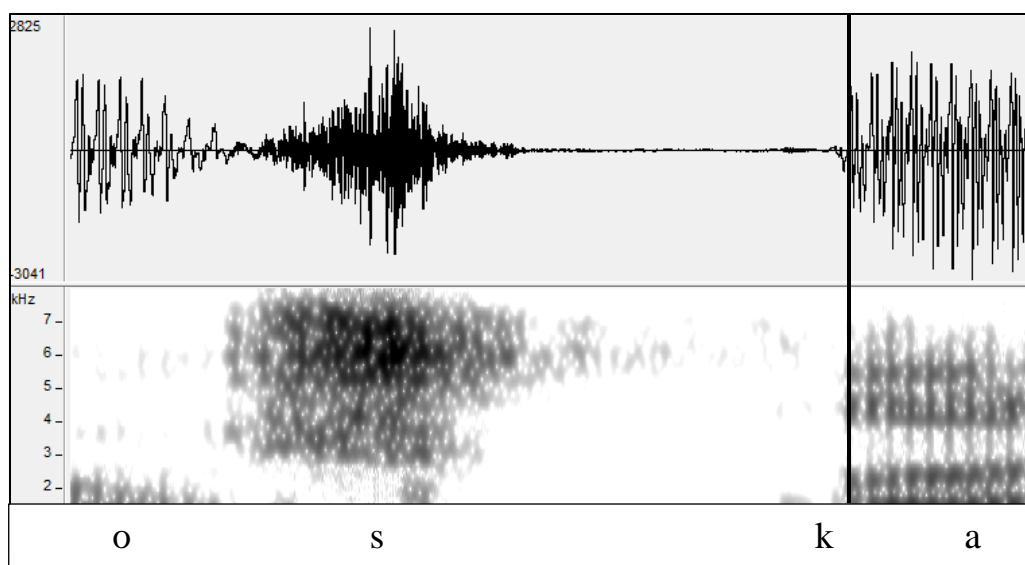
**Figure 4:** *Example of VOT Duration for a Postaspirated /t/ in “Voy a la costa ahora”.*<sup>10</sup>



<sup>10</sup> Speaker RS, token Voy\_a\_la\_costa\_ahora.26

There were also cases of tokens that had no release bar or notable VOT. These tokens were labeled as having a VOT duration of zero milliseconds and an example can be seen in figure 5 below.

**Figure 5:** Example of a Zero VOT Duration for a /k/ in “*Prefiero una rosca ahora*”.<sup>11</sup>



#### 4.4 Statistical Analysis

A quantitative analysis was carried out for the 2,234 tokens gathered from the sentence reading task completed by the Sevillian participants in order to better understand the factors conditioning the postaspiration in this particular dialect. All statistical analyses were performed using SPSS (Statistical Package for the Social Sciences) software, version 20.0 for Windows<sup>12</sup>. Postaspiration duration functioned as the dependent variable in all analyses. Each token was coded for six independent variables. The first three possible predictors are social in nature and include age group (19-29, 30-40 or 41+), gender (male or female) and level of education (trade school, university or higher education). The remaining three are linguistic factors and include the

<sup>11</sup> Speaker HL, token *Prefiero\_una\_rosca\_ahora.21*

<sup>12</sup> IBM Corp. Released 2011. IBM SPSS Statistics for Windows, Version 20.0. Armonk, NY: IBM Corp.

place of articulation of the following occlusive (bilabial, dental or velar), the location of the target cluster (within or over a word boundary) and the position of lexical stress in relation to the target cluster (preceding, following or nonadjacent).

Although a heavy majority of the analyzed tokens contained postaspiration, 23.2% of the tokens were produced with no measurable postaspiration duration. Table 3 below shows the overall distribution of the presence and absence of postaspiration present in the current data.

**Table 3:** *Overall frequency of postaspiration*

	Number of Tokens	Percentage of Data
<b>Absence of Postaspiration</b>	524	23.2%
<b>Presence of Postaspiration</b>	1710	76.8%
<b><i>Total</i></b>	<b>2234</b>	<b>100%</b>

As a result, the statistical analysis of these six variables and their effect on postaspiration is twofold. First, postaspiration duration is examined as a binary dependent variable, consisting of either the presence or the absence of positive postaspiration duration, through both a Binary Logistic Regression Model and a Mixed Effects Logistic Regression Model. Secondly, the effect of the same six independent variables is explored with postaspiration duration as a continuous dependent variable using a Univariate ANOVA analysis, using only tokens containing postaspiration. This bipartite analysis provides insight into the prediction of the presence of postaspiration and also the conditioning of the duration when present. Also investigated is the impact of integrating speaker as a random effect into each model.

An additional Univariate ANOVA analysis is conducted to determine the effect of the different phonetic realizations of the underlying sibilant /s/ on the duration of postaspiration. As discussed in Section 4.3, each token was categorized as being produced as either a fully realized sibilant [s], an aspirate [h] or a phonetic zero [Ø]. This variable was unable to be manipulated by

the experimenter and as a result, it is not included as an independent factor in the aforementioned analyses; however, its relation to postaspiration is essential to better understand this phenomenon.

Thirdly, potential correlations present between the duration of postaspiration and the duration of the adjacent segments are investigated through a series of Pearson Correlation tests. These include the duration of the preceding vowel, the duration of the closure for the following occlusive and if present, the duration of the fully realized or aspirated sibilant. These durational relationships help explain the possible articulatory trade-offs responsible for the presence of postaspiration.

Finally, several comparisons of means and cross-tabulations will be presented to discuss a few noteworthy tendencies found in the data for independent variables that were not found by the statistic models to be significant. Despite their lack of statistical significance, they help in better understanding the distribution of postaspiration and the phonetic mechanisms that drive its production.



## 5. Results

### 5.1 *Postaspiration as a binary dependent variable*

A logistic regression analysis was completed with the presence or absence of postaspiration as a binary dependent variable. All six categorical independent variables were included in the analysis. Table 4 displays the results of this initial analysis. Since the Wald statistic (Hosmer and Lemeshow, 2000) is an indicator of each independent variable's relative strength in predicting the outcome of the dependent variable, these values are listed along with their significance level<sup>13</sup>. According to these values, the place of articulation of the following occlusive has the strongest influence on the presence of postaspiration (Wald=281.781,  $p=.000$ ). A simple means analysis shows that both the dental and velar places of articulation predict the presence of postaspiration significantly more than the bilabial place of articulation ( $p=.001$ ) but the two groups do not differ significantly from each other ( $p=.221$ ). Education level has the next strongest effect on the presence of postaspiration (Wald=40.322,  $p=.000$ ), with a trade school education predicting a significantly higher likelihood of postaspiration than either a university or higher education. Finally, age group was also found to be a significant variable (Wald=13.898,  $p=.001$ ), with the youngest age group predicting postaspiration significantly more than either the middle or oldest age groups, which did not differ from each other ( $p=.980$ ). Neither gender (Wald=3.624,  $p=.057$ ), type of word boundary (Wald=.925,  $p=.336$ ) nor position of lexical stress (Wald= .255,  $p=.880$ ) were selected as strong predictors of the presence of postaspiration.

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<sup>13</sup> Alpha value is set at .05 for all statistical analyses

\*\*\* = Highly significant ( $p < .001$ )

\*\* = Significant ( $p < .01$ )

\* = Not significant ( $p < .05$ )

**Table 4:** *Results of the logistic regression analysis for presence or absence of postaspiration*

<b>Independent Variables</b>	<b>Wald</b>	<b>df</b>	<b>Significance</b>
<b>Place of Articulation</b>	281.781	2	.000***
<b>Education Level</b>	40.322	2	.000***
<b>Age Group</b>	13.898	2	.001***
<b>Gender</b>	3.624	1	.057*
<b>Type of Word Boundary</b>	.925	1	.336*
<b>Position of Stress</b>	.255	2	.880*

$N = 2234$ , Model  $X^2 = 340.805$ ,  $df = 10$ ,  $p = .000$

However, it is essential to note that the aforementioned model is only capable of analyzing the statistical significant of the six fixed independent variables without accounting for any possible random effects out of the control of the experimenter. As a result, a mixed effects logistic regression analysis was computed using the same dependent and independent variables discussed for the previous model; however, speaker was added as a random effect. As can be seen from Table 5 below, the independent variables selected as significant are notably different.

**Table 5:** *Results for the mixed effects logistic regression with speaker as a random effect*

<b>Independent Variables<sup>14</sup></b>	<b>F</b>	<b>df1</b>	<b>df2</b>	<b>Significance</b>
<b>Place of Articulation</b>	149.055	2	2.233	.000***
<b>Type of Word Boundary</b>	1.187	1	2.223	.276*
<b>Education Level</b>	1.161	2	2.233	.314*
<b>Gender</b>	.494	1	2.233	.482*
<b>Age Group</b>	.664	2	2.233	.515*
<b>Position of Stress</b>	.119	2	2.233	.887*

$N = 2234$

In this adjusted model, only place of articulation is selected as a statistically significant predictor of the presence of postaspiration. A pairwise comparison analysis further explains the

<sup>14</sup> The Wald statistic is not available for Mixed Effects Logistic Regression analyses

effects of the different subcategories of this independent variable. While both dental and velar places of articulation predict the presence of postaspiration significantly more than the bilabial ( $p=.001$ ), they do not differ significantly from each other ( $p=.065$ ) when all six independent factors are considered. The overall frequencies of both the presence and absence of postaspiration by all three places of articulation can be seen in Table 6 below. It is clear that both dental and velar places of articulation favor the presence of postaspiration more than the bilabial place of articulation. A chi-squared test reveals a significant relationship between the variables,  $\chi^2$  (2,  $N=2234$ )=310.392,  $p=.001$ , which is then confirmed by a Cramér's  $V$  post-hoc test<sup>15</sup>, Cramér's  $V = .373$ ,  $p=.001$ .

**Table 6:** *Overall frequencies of postaspiration by place of articulation of the following occlusive*

	ABSENCE	PRESENCE	TOTAL
BILABIAL	46.7% (341)	54.1% (394)	32.9% (735)
DENTAL	10.7% (80)	89.3% (671)	33.6% (751)
VELAR	13.8% (103)	86.2% (645)	33.5% (748)
<b>TOTAL % OF TOKENS</b>	23.5% (524)	76.5% (1710)	100.0% (2234)

$$\chi^2 (2, N=2234) = 310.392, p = .001, \text{Cramér's } V = .373, p = .001$$

Thus, the analyses presented above show that when the statistical model is not fitted with speaker as a random effect, the independent variables of place of articulation, education level and age group are the most significant predictors of the presence or absence of postaspiration. However, with the addition of speaker as a random effect, the only remaining significant predictor is the place of articulation of the following occlusive<sup>16</sup>. This shows the robustness of

<sup>15</sup> A Cramér's  $V$  test is used in this case since the contingency table is 2x3 and a Chi-squared test is not sufficient to demonstrate the strength of each independent group. A Cramér  $V$  number over .3 is considered to represent a strong association between the variables and the  $p < .001$  confirms the Chi-squared result, showing that these associations are not due to chance or large sample size.

<sup>16</sup> The implications of the addition of speaker as a random effect will be discussed in detail in section 5.5.

this independent variable and its strength as a predictor of postaspiration. The quantitative data analysis will be expanded in the following section with a discussion of the statistical analyses in which postaspiration is analyzed as a continuous dependent variable.

## *5.2 Postaspiration as a continuous dependent variable*

The next stage of analysis consists of investigating the conditioning effects of the independent variables on postaspiration duration when it is studied as a continuous dependent variable. The previous section showed that the place of articulation of the following occlusive is the only reliably significant independent variable in predicting the presence or absence of postaspiration. The focus of this current section then is to better understand the conditioning factors of the duration of postaspiration when produced. Thus, only the 1710 tokens that were produced with postaspiration have been included in this section of the data analysis and those without were excluded. Additionally, the elimination of 524 tokens with postaspiration durations of zero milliseconds provided a normally distributed set of data appropriate for the following statistical models. Also shown in Section 5.1, the addition of speaker as a random effect is capable of influencing the significance of the independent variables. Thus, all six categorical independent variables (age group, gender, education level, place of articulation, type of word boundary and position of lexical stress) were subjected to two univariate ANOVA tests with postaspiration duration as the dependent variable, one with and one without speaker as a random effect.

First, the results for the Univariate ANOVA without speaker as a random effect are presented below in Table 7. Five of the six independent factors, both social and linguistic, were

found to be significant predictors of postaspiration duration<sup>17</sup> ( $p=.001$ ), with the exception of gender ( $p=.700$ ). Of the significant factors, only the position of lexical stress was found to have a slightly lower significance level than the other variables ( $p=.031$ )<sup>18</sup>.

**Table 7:** *Results of a univariate ANOVA without speaker as a random effect*

	<b>F</b>	<b>df1</b>	<b>df2</b>	<b>Significance</b>
<b>Age</b>	24.609	2	1.700	.000***
<b>Education Level</b>	18.539	2	1.700	.000***
<b>Place of Articulation</b>	90.817	2	1.700	.000***
<b>Type of Word Boundary</b>	26.445	1	1.700	.000***
<b>Position of Stress</b>	3.743	2	1.700	.031**
<b>Gender</b>	15.710	1	1.700	.700*

Secondly, a univariate ANOVA model was fitted with the same independent and dependent variables as the analysis above but with the addition of speaker as a random effect. As can be seen in Table 8 below, only the linguistic factors place of articulation ( $p=.001$ ), type of word boundary ( $p=.001$ ) and position of lexical stress ( $p=.006$ ) were found to be significant predictors. All social factors were eliminated as significant predictors with the addition of speaker as a random effect<sup>19</sup>.

**Table 8:** *Results of a univariate ANOVA with speaker as a random effect*

	<b>F</b>	<b>df1</b>	<b>df2</b>	<b>Significance</b>
<b>Place of Articulation</b>	135.714	2	1.700	.000***
<b>Type of Word Boundary</b>	38.289	1	1.700	.000***
<b>Position of Stress</b>	5.129	2	1.700	.006***
<b>Age</b>	1.283	2	1.700	.277*
<b>Education Level</b>	0.786	2	1.700	.375*
<b>Gender</b>	0.268	2	1.700	.605*

<sup>17</sup> The independent variables that maintain a significance level lower than .05 when speaker is added as a random effect will be discussed in detail in the following section.

<sup>18</sup> Significant interactions found within and between social and linguistic factors will be discussed in Section 6.4

<sup>19</sup> The tendencies and comparison of means for the social factors will be presented and discussed in Section 6.4

Next, a simple means effect analysis allows for a more detailed investigation of the linguistic factors by showing the significant relationships within each factor group. These results can be seen in Table 9 below. In this table, the last subcategory within each of the three independent variables is the reference group. That is to say, each subcategory of a particular variable is compared to the reference group in order to show significant differences.

**Table 9:** *Results of a simple means effect test from the univariate ANOVA with speaker as a random effect (Velar place of articulation, across word boundary and following stress as the reference groups)*

	Coefficient	Significance
<b>Place of Articulation – Bilabial</b>	-11.790	.000***
<b>Place of Articulation – Dental</b>	-2.400	.000***
<b>Place of Articulation – Velar</b>	0 <sup>20</sup>	
<b>Type of Boundary – Within Word</b>	4.852	.000***
<b>Type of Boundary – Across Word</b>	0 <sup>19</sup>	
<b>Position of Stress – Nonadjacent</b>	.432	.544*
<b>Position of Stress – Preceding</b>	2.635	.002***
<b>Position of Stress – Following</b>	0 <sup>19</sup>	

First, the strongest independent factor is the place of articulation of the following voiceless occlusive. The simple means effect analysis shows that both the bilabial group and the dental group differ significantly from the velar group<sup>21</sup> ( $p=.001$ ). A negative coefficient shows that both bilabial and dental places of articulation reliably predict a shorter duration of postaspiration than that of the velar place of articulation. The mean durations in milliseconds of the postaspiration measured for each place of articulation is presented in Table 10 below and confirm the findings of the simple means effect analysis.

<sup>20</sup> Final subcategory of each independent variable is marked with zero, as a comparison with itself is redundant.

<sup>21</sup> A rearrangement of the reference group shows that bilabial and dental places of articulation are also significantly different ( $p=.001$ )

**Table 10:** *Comparison of means of postaspiration durations for all three places of articulation*<sup>22</sup>

	Mean Duration of Postaspiration (ms)	Total Number of Tokens	Standard Deviation	% of Total Tokens
<b>BILABIAL</b>	26.401	397	11.187	23.2%
<b>DENTAL</b>	35.376	669	15.625	39.1%
<b>VELAR</b>	36.924	644	14.115	37.7%
<b>TOTAL</b>	33.875	1710	14.722	100.0%

A separate univariate ANOVA with place of articulation as the only independent variable and postaspiration duration as the dependent variable with only the tokens with positive postaspiration duration was conducted as well,  $F(2, 1709)=74.322$ ,  $p=.001$ . In the results of a Tukey HSD post-hoc test, the mean duration of postaspiration for the bilabial occlusive remain statistically different from both the dental and velar occlusives ( $p = .001$ ), as predicted by the previous model, but the dental and velar occlusives do not differ significantly from each other ( $p = .272$ ). Thus, occlusives with a velar place of articulation are only reliable predictors of significantly longer postaspiration than those with a dental place of articulation when all five other independent variables remain fixed. When place of articulation is included as the only independent factor, the significance of postaspiration duration difference between the dental and the velar categories is lost. Further explanation of these implications is given in Section 5.5.

The next most significant independent variable from Table 8 is the type of boundary in which the target cluster is positioned, either within the lexical word or over a word boundary. The simple means effect analysis presented in Table 9 shows that a target cluster located within a word is a significant predictor of longer postaspiration durations than that of a target cluster located over a word boundary ( $p=.001$ ) An additional one-way ANOVA with type of boundary as the only independent variable and postaspiration as a continuous dependent variable confirm

<sup>22</sup> Only tokens with positive postaspiration are included.

the significance findings,  $F(1, 1708)=69.744$ ,  $p=.000$ . The comparison of mean durations of postaspiration for both boundary types, in Table 11 below, further demonstrates these findings.

**Table 11:** *Comparison of means of postaspiration durations for all word boundary types*<sup>23</sup>

	Mean Duration of Postaspiration (ms)	Total Number of Tokens	Standard Deviation	% of Total Tokens
<b>WITHIN</b>	37.302	718	16.666	42.0%
<b>ACROSS</b>	31.395	992	12.577	58.0%
<b>TOTAL</b>	33.875	1710	14.722	100.0%

The third and final significant linguistic factor found in Table 8 is the location of lexical stress in relation to the target cluster. The results of a simple means effect analysis in Table 9 show that a preceding stressed vowel predicts longer postaspiration durations than a following stressed vowel ( $p=.001$ ). However, the postaspiration duration for target clusters with a following stressed vowel and a nonadjacent stressed vowel do not differ significantly ( $p=.544$ ). An additional one-way ANOVA with stress pattern as the only independent variable and postaspiration duration as a continuous dependent variable was also conducted,  $F(2,1707)=27.411$ ,  $p=.001$ . Results from a Tukey HSD post hoc test confirm the significant difference between the mean duration of postaspiration for a preceding stressed vowel environment and both following and nonadjacent stressed vowel environments ( $p=.001$ ). Again, no significant difference was found between postaspiration of target clusters with a following stressed vowel or no adjacent stressed vowels ( $p=.092$ ). Table 12 below provides a comparison of the mean durations of postaspiration for all three stress patterns to better establish the findings.

<sup>23</sup> Only tokens with positive postaspiration are included.



**Table 12:** *Comparison of means of postaspiration durations for all three stress patterns*<sup>24</sup>

	Mean Duration of Postaspiration (ms)	Total Number of Tokens	Standard Deviation	% of Total Tokens
<b>PRECEDING</b>	38.640	367	17.824	21.5%
<b>FOLLOWING</b>	33.206	848	13.989	49.6%
<b>NONADJACENT</b>	31.490	495	12.475	28.9%
<i>TOTAL</i>	33.875	1710	14.722	100.0%

Due to an unequal distribution of tokens with positive durations of postaspiration across both the type of word boundary and the position of the lexical stress in relation to the target cluster<sup>25</sup>, an additional univariate ANOVA with speaker as a random effect was run for the following combinations of tokens and independent variables: the effect of preceding and following stress within a word boundary, the effect of following and nonadjacent stress over a word boundary and the effect of word boundary when the target cluster is followed by a lexically stressed vowel<sup>26</sup>. First, Table 13 shows the results of a univariate ANOVA with speaker as a random effect that examines the effect of preceding and following stress patterns on tokens with a word internal boundary. The same pattern of postaspiration duration as was found in the overall results presented in Table 12 above is found in this particular boundary environment as well. When in a word internal environment, significantly longer durations of postaspiration are found for preceding stress patterns than for following stress patterns. Second, Table 14 shows the results of a univariate ANOVA with speaker as a random effect that looks at the effect of following and nonadjacent stress patterns on tokens with a word external word boundary. Again, within this particular word boundary, the findings mirror those of the overall results for mean

<sup>24</sup> Only tokens with positive postaspiration are included.

<sup>25</sup> Word internally, tokens only existed with preceding and following stress patterns. Word externally, tokens only existed with following and nonadjacent stress patterns. As a result, only tokens with following stress were able to be examined over both types of word boundaries.

<sup>26</sup> Only when tokens are arranged in these three configurations can the interactions between the position of lexical stress and type of word boundary be examined statistically.

duration of postaspiration by stress pattern shown in Table 12 above. When located over a word boundary, there is no significant difference in postaspiration duration for either a following or nonadjacent stress pattern.

**Table 13:** *Results of a univariate ANOVA with speaker as a random effect examining the effect of preceding and following stress patterns on tokens with a word internal word boundary (N=718)*

Type of Boundary	Position of Stress	Effect on Postaspiration	Significance
Internal	Preceding	Longer Duration	.028
	Following	Shorter Duration	

**Table 14:** *Results of a univariate ANOVA with speaker as a random effect examining the effect of following and nonadjacent stress patterns on tokens with a word external word boundary (N=992)*

Type of Boundary	Position of Stress	Effect on Postaspiration	Significance
External	Following	Equal Durations	.812
	Nonadjacent		

Finally, Table 15 presents the results of another univariate ANOVA with speaker as a random effect examining the effect of word boundary in tokens with a following stress pattern. As was found in the overall mean durations of postaspiration by word boundary presented in Table 11, word internal boundaries favor significantly longer postaspiration than word external boundaries.

**Table 15:** *Results of a univariate ANOVA with speaker as a random effect examining the effect of internal and external word boundaries on tokens with a following stressed vowel (N=848)*

Position of Stress	Type of Word Boundary	Effect on Postaspiration	Significance
Following	Internal	Longer Duration	.000
	External	Shorter Duration	

Thus, despite the uneven distribution of tokens across both independent variables, position of stress and type of word boundary, the similar results found in the overall univariate ANOVA in Table 8 and the individual univariate ANOVAs in Tables 13, 14 and 15 show that preceding stress and word internal boundaries both significantly predict longer durations of postaspiration.

In conclusion, without the inclusion of speaker as a random effect, all social and linguistic factors are found to be significant predictors of the duration of postaspiration, with the exception of gender, when the dependent variable is analyzed as continuous. However, only linguistic factors are found to be significant predictors of the duration of postaspiration when speaker is included as a random effect. That shows that only linguistic variables can be considered reliable predictors. A series of simple mean effect analyses concluded that both dental and velar places of articulation, preceding stressed vowels and internal word boundaries predict significantly longer durations of postaspiration.

### *5.3 Effect of sibilant realization on postaspiration duration*

The underlying /s/ of each target cluster was categorized according to its phonetic realization; either as a sibilant [s], an aspirate [h] or a phonetic zero [Ø]<sup>27</sup>. Since these different allophones of the sibilant /s/ could not be purposefully manipulated by the experimenter, their effects have been analyzed separately from the other independent variables. The mean duration of postaspiration associated with each phonetic realization is shown in Table 16 below. It is clear that longer durations of postaspiration appear to be favored by the elided and aspirated forms, the two weakened variants of /s/. A mixed effects logistic regression analysis was conducted with the realizations of the sibilant as the independent variable and the duration of postaspiration as a

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<sup>27</sup> The acoustic guidelines used to delineate the three separate groups is presented in 4.3

continuous dependent variable and speaker set as a random effect<sup>28</sup>.

**Table 16:** *Comparison of means of postaspiration durations for all three phonetic realizations*<sup>29</sup>

	Mean Duration of Postaspiration (ms)	Total Number of Tokens	Standard Deviation	% of Total Tokens
<b>ELIDED</b>	38.359	998	14.056	58.4%
<b>ASPIRATED</b>	37.201	268	14.217	15.7%
<b>SIBILANT</b>	21.790	444	8.448	26.0%
<b>TOTAL</b>	33.875	1710	14.722	100.0%

The findings, shown in Table 17 below, confirm that the two weakened realizations pattern with significantly longer durations of postaspiration than does the fully produced sibilant ( $p=.001$ ).

**Table 17:** *Results of a simple means effect test for the three phonetic realizations of the sibilant from a univariate ANOVA with speaker as a random effect*<sup>29</sup> (sibilant as the reference group)

	Coefficient	Significance
<b>Realization of Sibilant – Aspirated</b>	13.835	.000***
<b>Realization of Sibilant – Elided</b>	13.835	.000***
<b>Realization of Sibilant – Sibilant</b>	0 <sup>30</sup>	

The same simple means effect analysis with a different reference group reveals that the two weakened variants, aspirated and elided, do not differ significantly from each other in regards to the mean durations of postaspiration ( $p=.763$ ). These results are presented below in Table 18.

**Table 18:** *Results of a simple means effect test for the three phonetic realizations of the sibilant from a univariate ANOVA with speaker as a random effect*<sup>29</sup> (elided as the reference group)

	Coefficient	Significance
<b>Realization of Sibilant – Sibilant</b>	-13.835	.000***
<b>Realization of Sibilant – Aspirated</b>	0.267	.763*
<b>Realization of Sibilant – Elided</b>	0 <sup>30</sup>	

<sup>28</sup> The analysis was run both with and without speaker as a random effect. No difference was found in significance between the two analyses.

<sup>29</sup> Only tokens with positive postaspiration are included.

<sup>30</sup> Final subcategory of the independent variable is marked with zero, as a comparison with itself is redundant.

Thus, longer postaspiration durations are able to be predicted by the type of phonetic realization of the underlying sibilant preceding the voiceless occlusive. The results thus far in this section have shown that the reduced variants, the aspirated [h] and the phonetic zero [Ø], pattern with longer durations of postaspiration while the fully realized sibilant [s] patterns significantly with shorter durations of postaspiration.

The interactions between the three phonetic realizations of the underlying /s/ and the other linguistic factors also merit investigation. Even though it is not considered a true independent variable in this study<sup>31</sup>, its importance in the prediction of the duration of postaspiration has been demonstrated and the distribution of the realizations across the varied linguistic environments provides additional insight into the phenomenon. First, the distribution of each phonetic realization by place of articulation is present in Table 19 below. It clear that the elided, or phonetic zero [Ø], realization of the underlying sibilant /s/ is the most favored in this dialect, representing 58.3% of the data. The next most common is the fully realized sibilant [s] in 28.5% of the data<sup>32</sup> and finally the aspirated variant [h] being realized in only 13.2% of the data<sup>33</sup>. In regards to the distribution across the three places of articulation, the realizations seem relatively stable in that percentages for each place of articulation follow the overall pattern: the phonetic zero being the most common, followed by fully realized sibilant and finally the aspirated variant. It is interesting to note that the bilabial place of articulation patterns with the highest percentage of elided sibilants (66.8%) and the lowest percentage of aspirated sibilants (7.9%) while the dental place of articulation consists of the most evenly distributed realizations.

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<sup>31</sup> Due to the fact that it was not directly manipulated by the experimenter like the other linguistic environments.

<sup>32</sup> It is important to note that the experimenter acknowledges the possible influence of the more formal, orthographic nature of the experimental task on the higher rates of fully realized sibilants, despite the fact that this dialect is known as an /s/ reducing variety of Spanish.

<sup>33</sup> All past studies have acknowledged the difficulty of delineating and categorizing aspiration and it is possible that this difficulty has influenced the percentage of aspiration in this current study.

A chi-squared test reveals a significant relationship between the variables,  $\chi^2$  (4, N=2233) = 36.857,  $p = .001$ , which is then confirmed by a Cramér's  $V$  post-hoc test<sup>34</sup>, Cramér's  $V = .091$ ,  $p = .001$ .

**Table 19:** *Distribution of phonetic realizations of /s/ by place of articulation*<sup>35</sup>

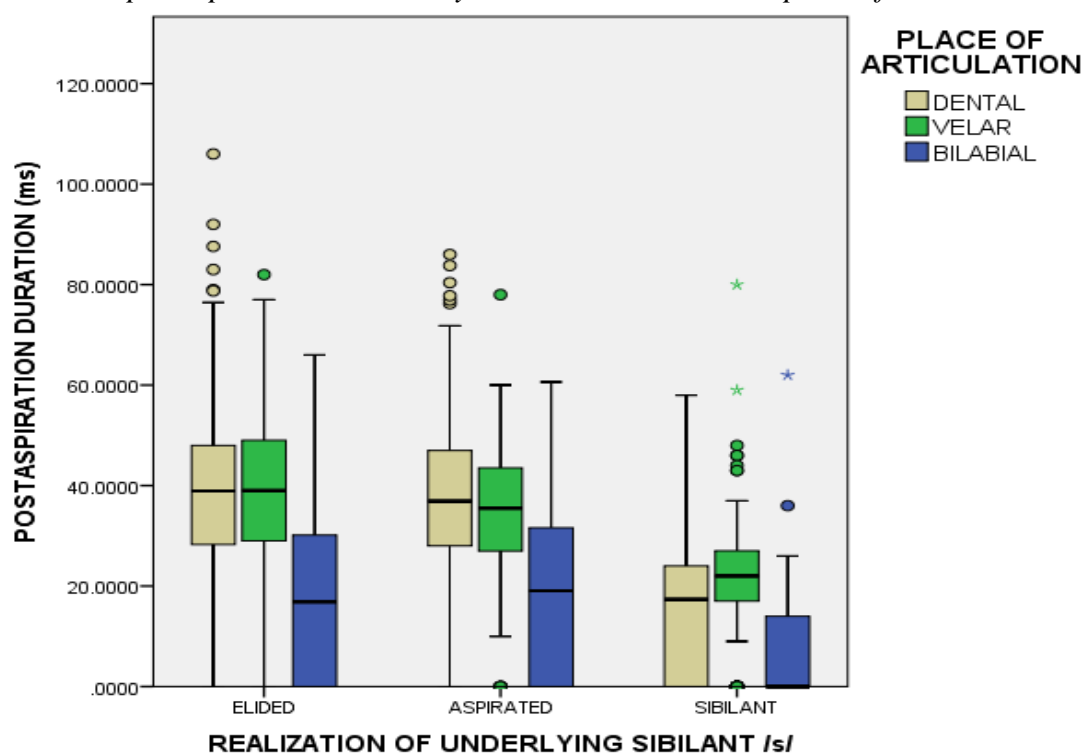
REALIZATION OF UNDERLYING SIBILANT	PLACE OF ARTICULATION			TOTAL
	Velar	Dental	Bilabial	
Elided	61.1% (457)	47.2% (354)	66.8% (491)	58.3% (1302)
Aspirated	10.6% (79)	21.1% (158)	7.9% (58)	13.2% (295)
Sibilant	28.3% (748)	31.7% (238)	25.3% (186)	28.5% (636)
<b>TOTAL</b>	100% (735)	100% (750)	100% (748)	100% (2233)

$$\chi^2 (4, N=2233) = 36.857, p = .001, \text{Cramér's } V = .091, p = .001$$

Of interest is the impact of these distributions on the production of postaspiration of the following voiceless occlusive. In Figure 6 below, the duration of postaspiration is presented through a comparison of the sibilant realization and the place of articulation of the following occlusive. It is clear that both the reduced variants, elided and aspirated, are patterning similarly in the duration of postaspiration for each following place of articulation. When these reduced variants are followed by both the dental and velar places of articulation, significantly longer durations of postaspiration are predicted; whereas, the unreduced fully realized sibilant patterns with significantly shorter postaspiration duration across all places of articulation.

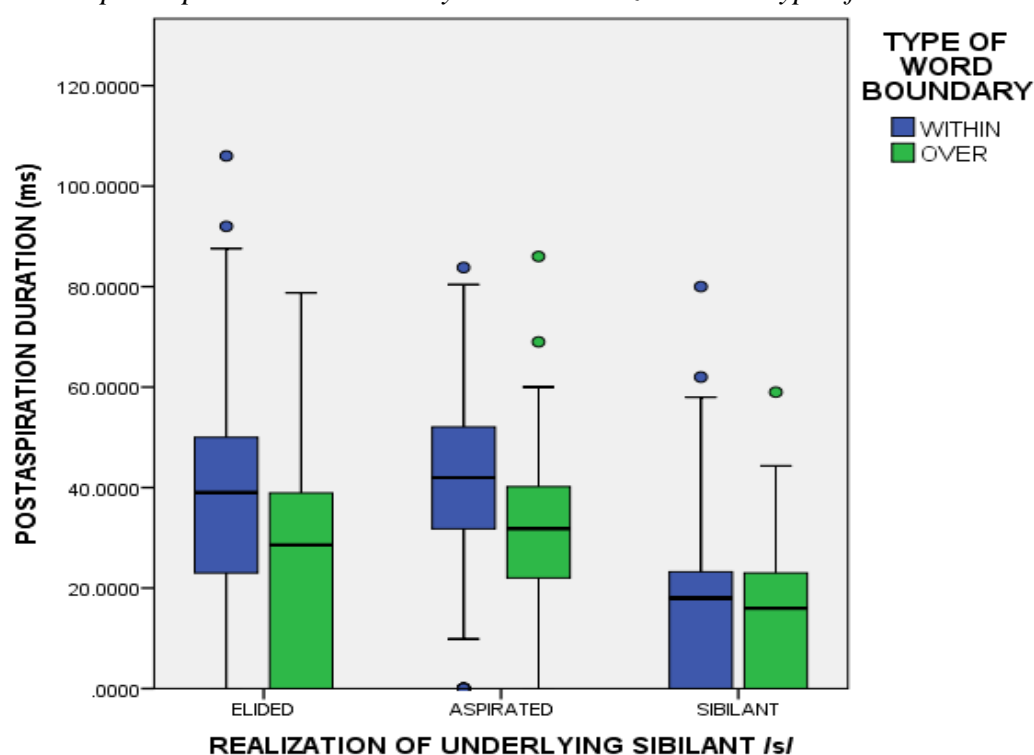
<sup>34</sup> A Cramér's  $V$  test is used in this case since the contingency table is 3x3 and a Chi-squared test is not sufficient to demonstrate the strength of each independent group. A Cramér  $V$  number between .06 and .01 is considered to represent a significant yet weak association between the variables and the  $p < .001$  confirms the Chi-squared result, showing that these associations are not due to chance or large sample size.

<sup>35</sup> All tokens, with and without postaspiration, are included in this table.

**Figure 6:** *Mean postaspiration duration by sibilant realization and place of articulation.*

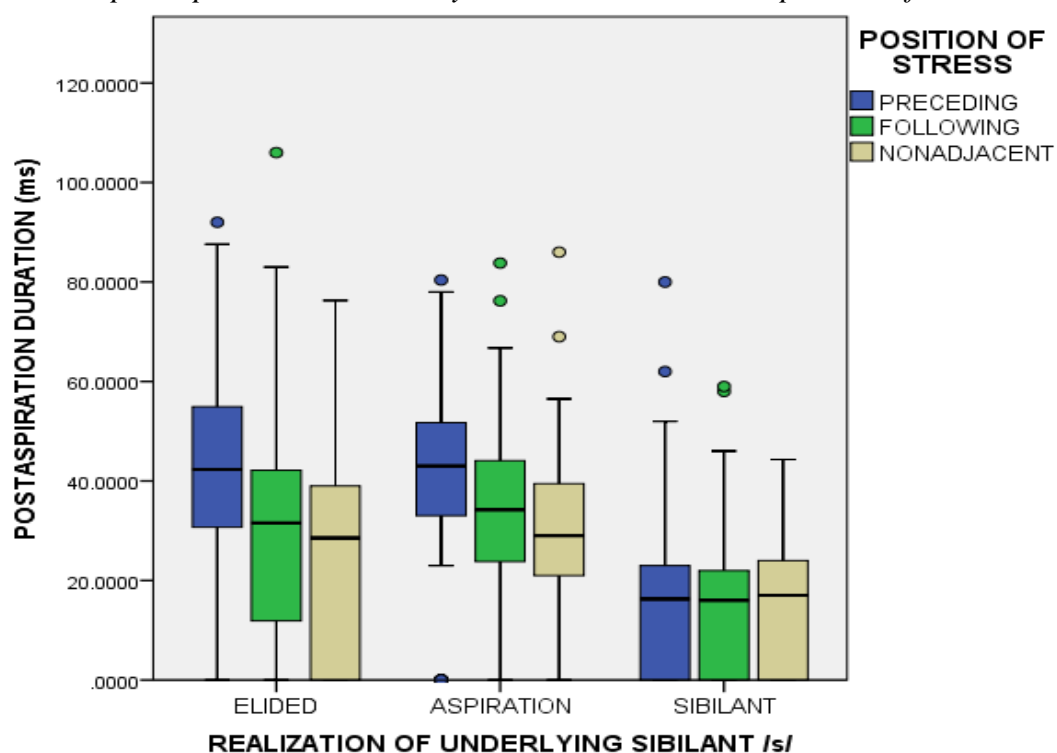
The next linguistic variable to be investigated for the distribution of the phonetic realizations of the underlying sibilant /s/ is the position in which the target cluster is placed, either within or over a word boundary. Figure 7 below shows that again the reduced variants pattern similarly while the fully realized sibilant behaves notably differently. While the elided and aspirated variants pattern with longer postaspiration durations within a word boundary, the full sibilant appears to have no effect on postaspiration in either boundary position. Also of note, a comparison of means for each realization by word boundary reveals that 67.5% of the aspirated tokens are produced over word boundaries, showing a clear preference for either the elided variant or the fully realized sibilant in word internal environments<sup>36</sup>.

<sup>36</sup> The implications of this finding will be discussed in Section 6.

**Figure 7:** *Mean postaspiration durations by sibilant realization and type of word boundary*

Finally, the effect of the different sibilant realizations on postaspiration duration over different positions of lexical stress reveals similar patterns as the aforementioned linguistic factors. As seen in Figure 8 below, the reduced variants pattern similarly while the fully realized sibilant remains stable across all three types of stress patterns. Both the elided and the aspirated variants pattern with the longest postaspiration durations when preceded by a stress vowel with notably shorter durations with a following stressed vowel or nonadjacent lexical stress. However, the fully realized sibilant demonstrates no stress pattern effect on the prediction of postaspiration durations.



**Figure 8:** *Mean postaspiration durations by sibilant realization and position of stress*

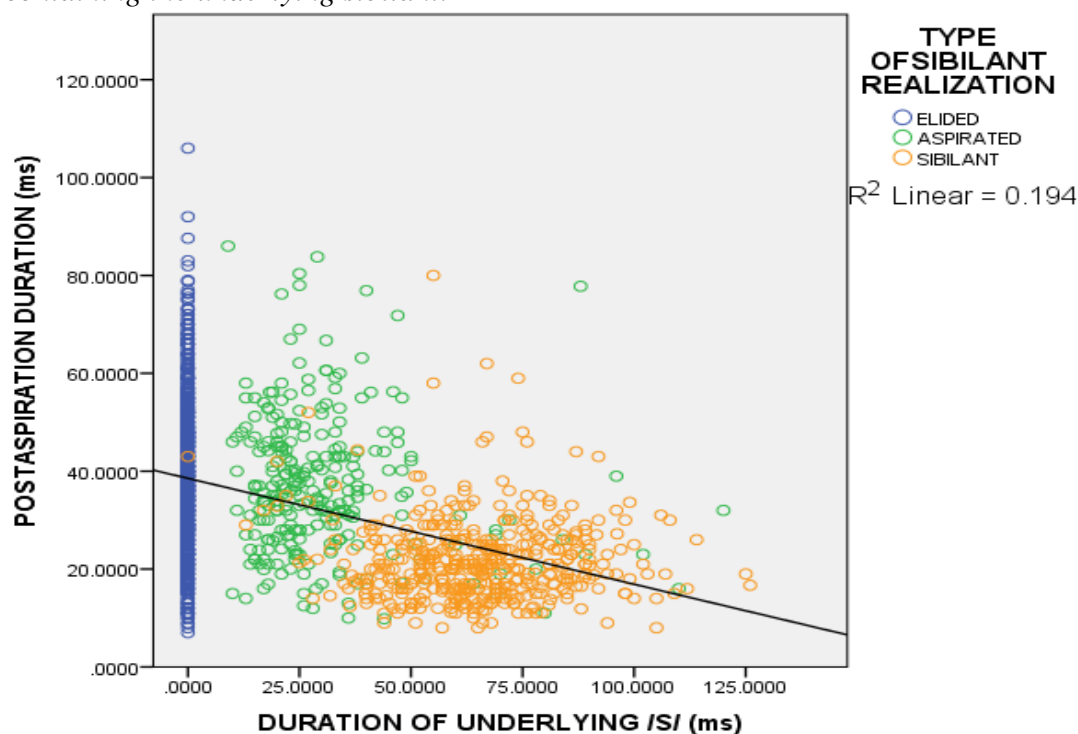
To conclude, the three possible phonetic realizations of the underlying sibilant preceding voiceless occlusives has been shown to be a significant predictor of postaspiration duration. Especially when analyzed in conjunction with the other linguistic variables in this study, it is clear that the two reduced realizations of /s/, the aspirated and elided variants, not only both predict significantly longer postaspiration durations but also behave similarly in all three linguistic environments while the fully realized sibilant remains stable.

#### 5.4 Correlation relationships of adjacent segment durations

A series of Pearson correlation tests were conducted to investigate the effect of the duration of segments adjacent to the target cluster in order to help explain potential articulatory trade-offs. The first duration investigated is that of the segment representing the underlying /s/

preceding the closure for the following occlusive<sup>37</sup>. A two-tailed Pearson correlation test run with the 1710 tokens with positive postaspiration durations reveals a significant negative correlation between the duration of the phonetic realization of the underlying /s/ and the duration of postaspiration ( $r = -.441$ ,  $n=1710$ ,  $p=.001$ )<sup>38</sup>. A graphic representation of this relationship can be seen in Figure 9 below. As the duration of the underlying /s/ segment increases, the duration of postaspiration decreases. Additionally, this graph shows that the duration of the segment containing the underlying sibilant tends to be longer when the /s/ is fully realized as a sibilant [s]. This corroborates the findings in Section 5.3 since the fully realized sibilants patterned with shorted durations of postaspiration.

**Figure 9:** *Correlation between postaspiration duration and the duration of the preceding segment containing the underlying sibilant.*



<sup>37</sup> Please refer to section 4.3 for an explanation and examples of the acoustic criteria used to measure all of segments in the spectrogram.

<sup>38</sup> The same test with all tokens also was conducted and was found significant,  $r = -.294$ ,  $n=2234$ ,  $p=.001$

Secondly, the potential correlation between the preceding vowel and the duration of postaspiration was investigated. A Pearson correlation test revealed that a moderately significant negative correlation exists between the duration of these two segments ( $r = -.058$ ,  $n=1710$ ,  $p=.016$ )<sup>39</sup>. Thus, as the duration of the vowel segment preceding the target cluster decreases, the duration of postaspiration increases. However, several previous studies (Gerfen 2002, Torreira 2006, 2012) have discussed the methodological difficulties involved in delimiting the boundary between the end of the vocalic segment and the onset of aspiration, one of the three potential phonetic realizations of the segment containing the underlying sibilant. A Pearson correlation test for the duration of the preceding vowel and the duration of the following segment containing the underlying sibilant revealed a significant positive correlation ( $r=.225$ ,  $n=1710$ ,  $p=.001$ )<sup>40</sup>. This shows that both segments behave similarly and do not cancel each other out. As a result of the methodological decisions of past studies (Gerfen 2002, Torreira 2006) and the positive correlation of both segments, the vowel duration and the duration of the following segment containing the underlying sibilant were combined. A Pearson correlation test was conducted with the combined durations and the duration of postaspiration and a significant negative correlation was found ( $r = -.381$ ,  $n=1710$ ,  $p=.001$ )<sup>41</sup>. That means that as the duration of the entire preceding vowel + consonant (VC) segment decreases, postaspiration increases. Figure 10 below shows this negative correlation, as well as its relation to the phonetic realization of the underlying sibilant.

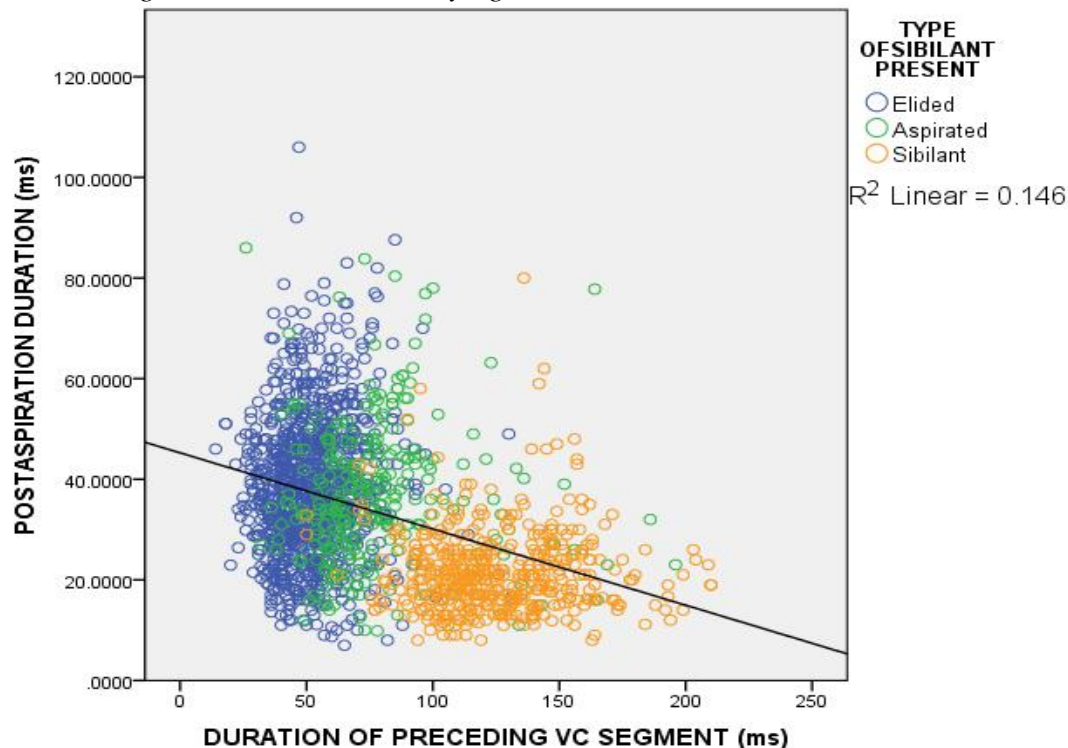
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<sup>39</sup> The same test with all tokens also was conducted and revealed similar results,  $r = -.056$ ,  $n=2234$ ,  $p=.011$

<sup>40</sup> The same test with all tokens also was conducted and revealed similar results,  $r = .264$ ,  $n=2234$ ,  $p=.001$

<sup>41</sup> The same test with all tokens also was conducted and revealed similar results,  $r = -.258$ ,  $n=2234$ ,  $p=.001$

**Figure 10:** *Correlation between postaspiration duration and the duration of the preceding VC segment containing a vowel and an underlying sibilant.*



According to the figure, it appears that VC sequences containing an elided sibilant tend to be much shorter than those containing a fully realized sibilant and pattern with longer postaspiration. This information also corroborates the findings in Section 5.3.

In conclusion, the relationship between adjacent segment durations and postaspiration durations were found to be significant. As the individual and combined durations of the preceding vowel and the preceding realization of the underlying /s/ decrease, the duration of postaspiration increases significantly. This negative correlation provides the basis for a discussion of articulatory trade-offs in Section 6.

### 5.5 Additional results and social tendencies

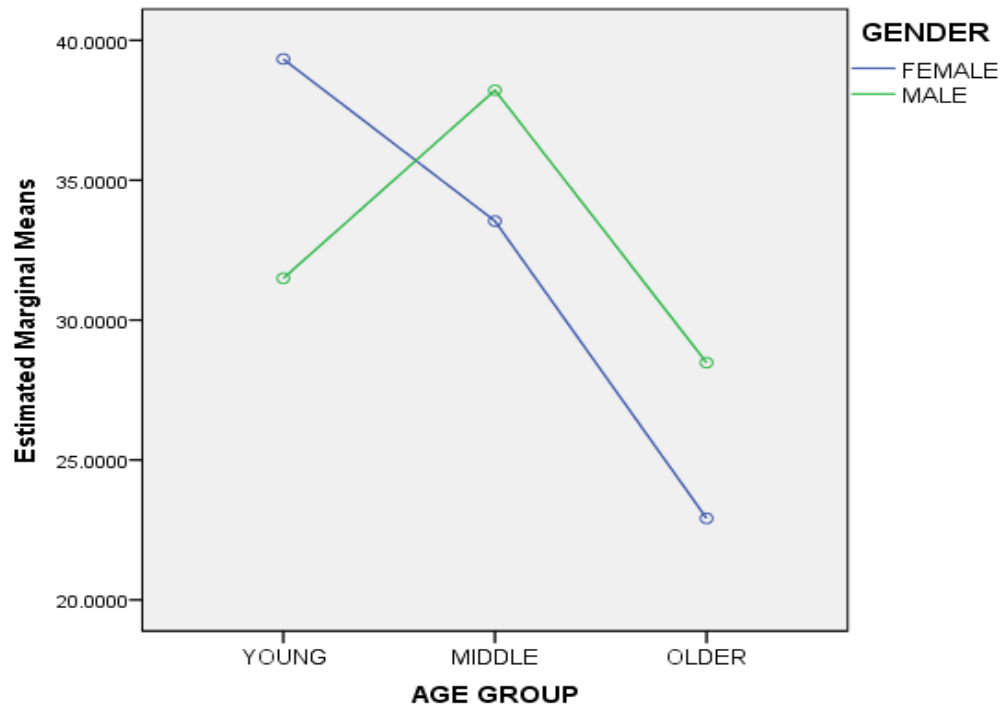
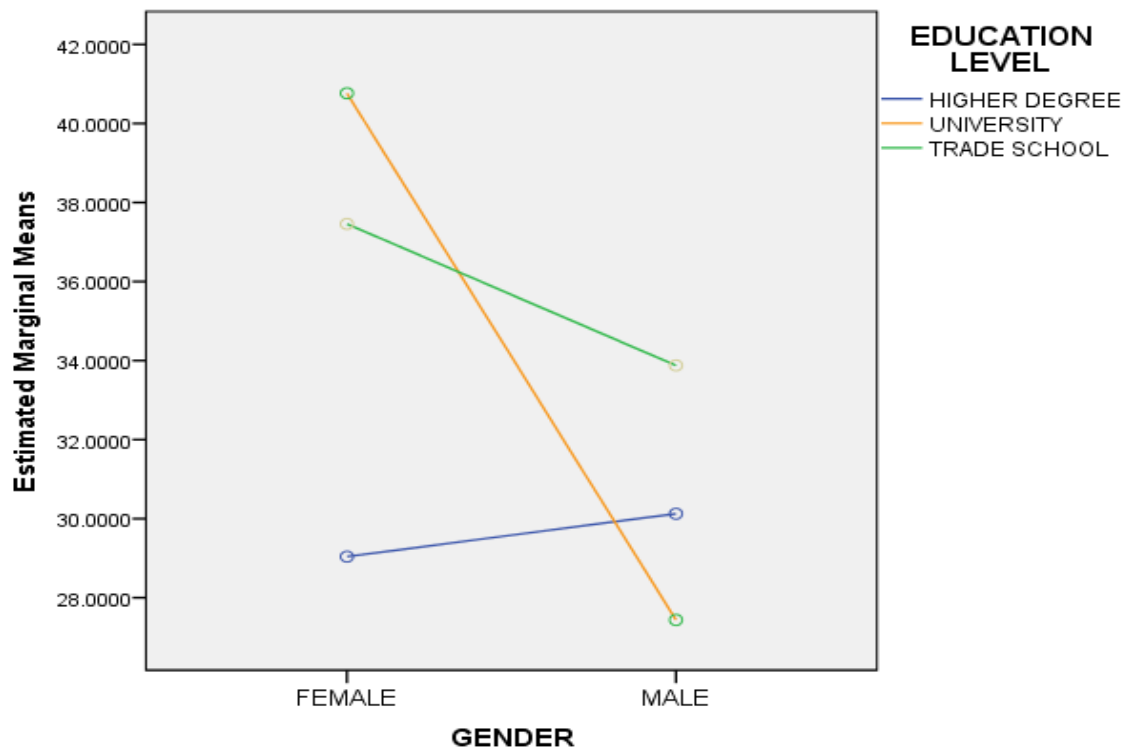
The statistical models in the previous subsections did not select any social factors as significant predictors of postaspiration when speaker was added as a random effect. However, a

univariate ANOVA and a comparison of means analysis provide insight into the trends evident in the data that would have possibly reached significant levels in the statistical models with a greater number of participants and tokens. The results of the univariate ANOVA without speaker as a random effect in Table 7 showed age group and education level to be significant ( $p=.001$ ), with significant interactions between age group and gender ( $p=.007$ ) and gender and education level ( $p=.001$ ). Beginning with age group, a Tukey HSD post-hoc test revealed that the older age group differed significantly with shorter postaspiration duration than both the younger and middle age groups ( $p=.001$ ). However, the two youngest age groups did not differ significantly from each other ( $p=.265$ ). As for education level, only the lowest and highest levels of education demonstrated a significant difference in that the group with a trade school education produced significantly longer postaspiration durations than those with a higher education ( $p=.001$ ) but those with a university education did not differ significant from either those with a trade school education ( $p=.051$ <sup>42</sup>) or those with a higher education ( $p=.165$ ). As for the significant interaction between age group and gender, females in the youngest age group produced the longest mean duration of postaspiration<sup>43</sup> yet men produced the longest durations for the two older age groups. This relationship can be seen graphically in Figure 11 below. A second interaction of gender and education level showed that females with a university education produced the longest mean durations of postaspiration of all education levels while males with a university level of education produced the shortest means of duration of all education levels. This interaction is presented graphically in Figure 12 below.

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<sup>42</sup> This significance level is just over the alpha value and it is possible that with a larger sample size the significance would become more prominent.

<sup>43</sup> It must be noted that this may be due to one particular speaker in this category that had the longest mean duration of postaspiration of all of the participants.

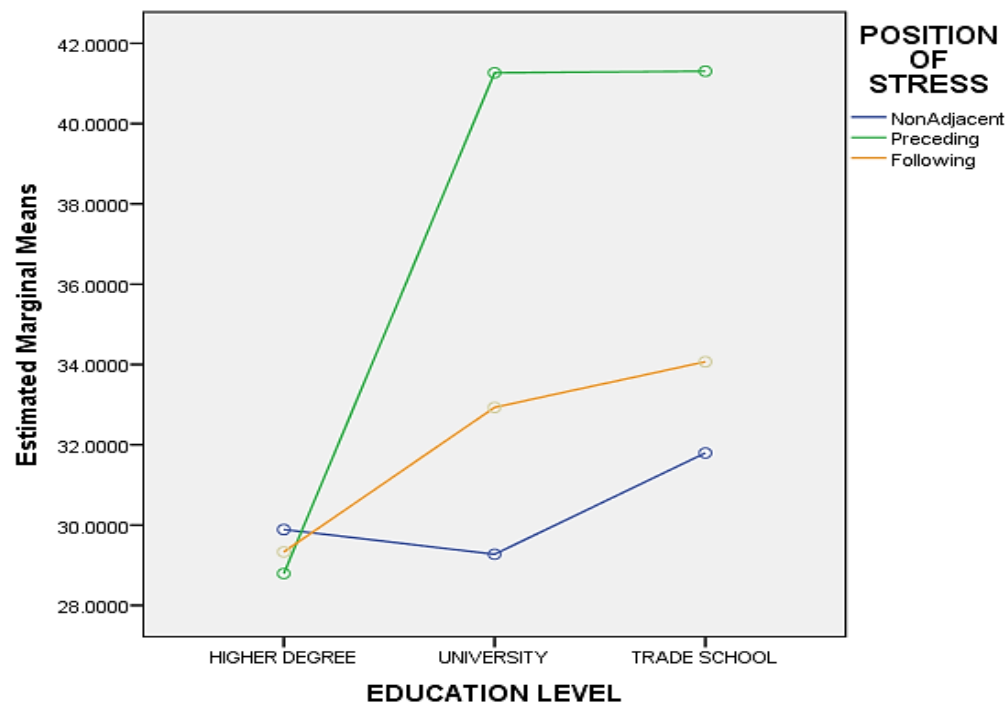
**Figure 11:** *Interaction plot for age group and gender***Figure 12:** *Interaction plot for education level and gender*

Thus, it appears that there exist tendencies towards younger women and speakers with a university education to produce longer durations of postaspiration. Also of interest, of younger

speakers with a university level education, only females show a tendency to favor longer postaspiration durations while male speakers notably disfavor it.

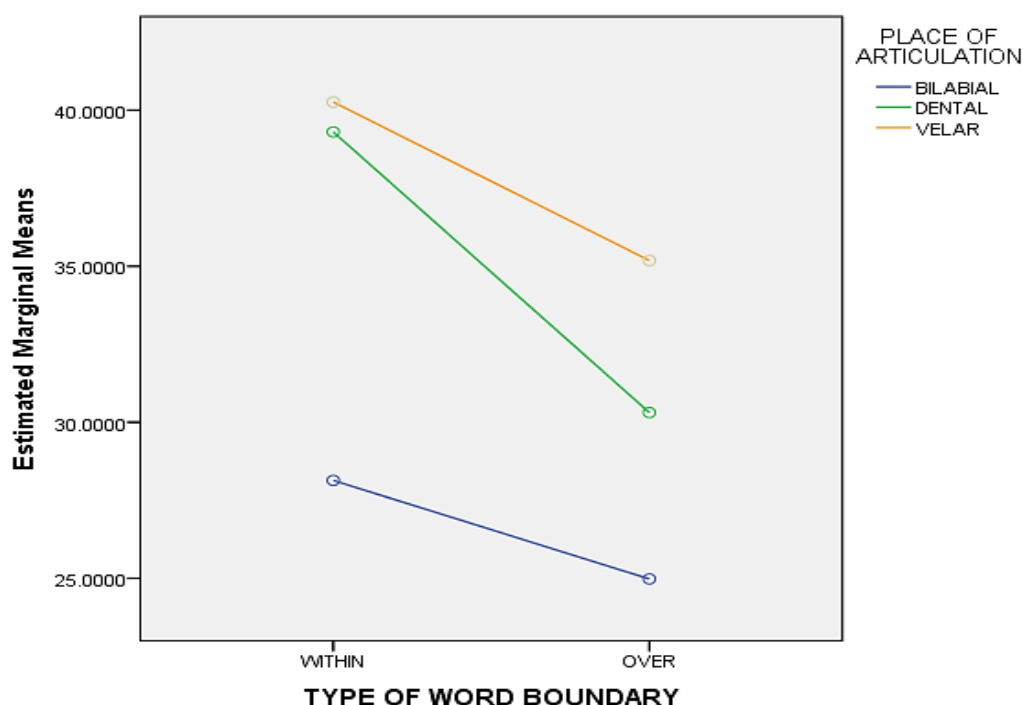
Two additional interactions from the aforementioned ANOVA involving linguistic factors were also found to be significant and merit additional investigation. These include an interaction between the social factor of education level and the linguistic factor of position of stress ( $p=.001$ ) and the two linguistic factors, place of articulation and type of word boundary ( $p=.001$ ). First, the interaction plot shown below in Figure 13 presents the interaction found between a speaker's level of education and the stress pattern of the target words. Speakers with the highest level of education show no notable change in duration of postaspiration dependent on the position of lexical stress in relation to the target cluster. However, both university level and trade school educated speakers demonstrate a drastic increase in mean durations of postaspiration for words with a preceding stressed vowel.

**Figure 13:** *Interaction plot for education level and position of stress*



Secondly, the significant interaction between two linguistic factors, the place of articulation of the following voiceless occlusive and the boundary type, show that in a word internal position, both the velar and dental places of articulation behave similarly in their prediction of significantly longer postaspiration durations than the bilabial place of articulation. However, when the target cluster is located over a word boundary, the mean duration of postaspiration for the velar place of articulation is significantly longer than that of both the dental and the bilabial groups. This shows that although the dental and velar voiceless stops are behaving similarly by patterning with long postaspiration in word internal environments, there is a tendency for the dental place of articulation to decrease its likelihood of long postaspiration durations over word boundaries. This relationship can be seen below in Figure 14.

**Figure 14:** *Interaction plot for type of word boundary and place of articulation*

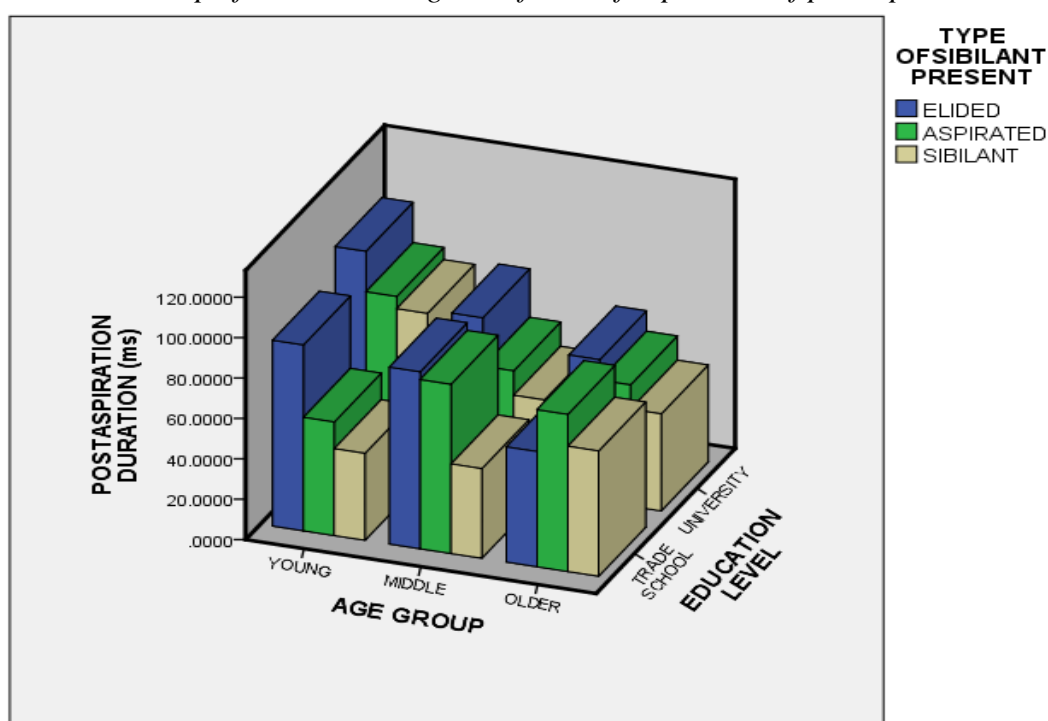


Thus, since the addition of speaker as a random effect to the statistical models results in the loss of significance for all social factors and their interactions, it appears that a great deal of

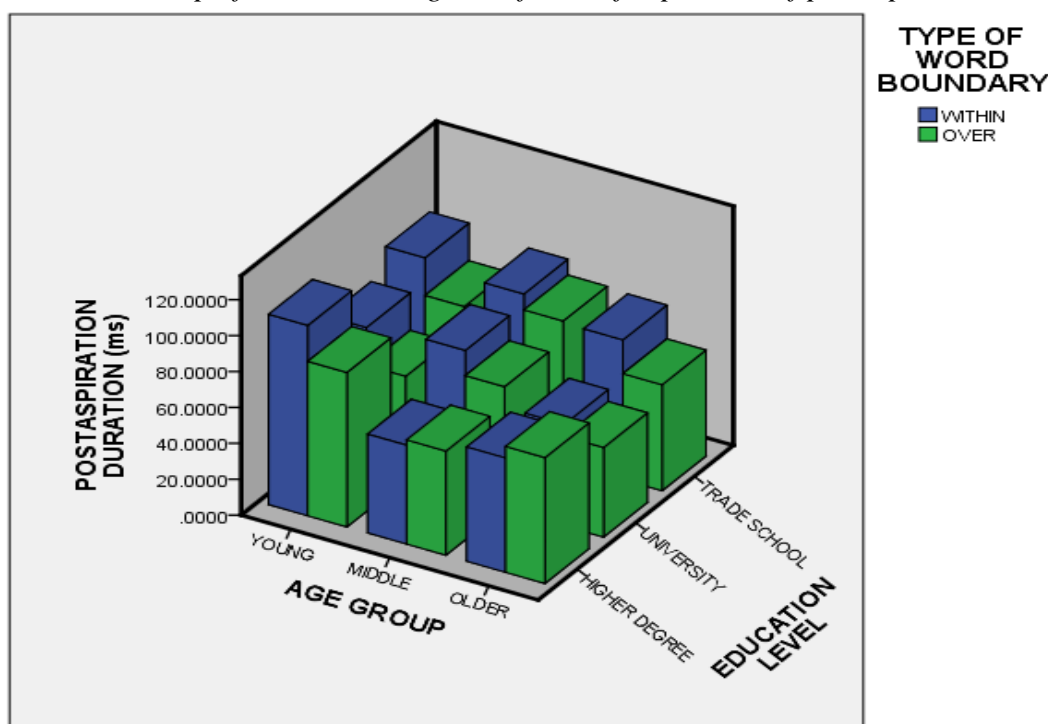


interspeaker variation is involved in this particular phenomenon. It is likely that an increase in the sample size would provide better insight into whether or not the social tendencies discussed above are truly significant. On the other hand, the fact that the social factors appear to be unreliable as predictors of postaspiration duration shows that the mechanisms behind this phenomenon may be mostly linguistic in nature. Further evidence of this is apparent in Figure 15 below where the duration of postaspiration is graphed by age group, education level and type of phonetic realization present for the underlying sibilant. Besides the fact that the younger age group tends to produce more elided sibilants with longer durations of postaspiration overall, a linguistic pattern independent of the social factors emerges. With only the exception of the oldest age group with a trade school education where a nonsignificant tendency is found for aspirated sibilants patterning with the longest postaspiration, all other groups produced longer durations of postaspiration with the elided sibilant followed by the aspirated variant, both of which are reduced forms of the sibilant. For all age groups and education levels, the fully realized sibilant patterns consistently with the shortest postaspiration duration. Similarly, Figure 16 below shows a similar trend in that the linguistic pattern found for producing longer postaspiration durations within a word boundary is found across all age groups and education levels with the exception the middle and older age groups with higher degree educations, whose difference in mean was not found to be significant ( $p=.245$ ). This again points to the idea that the phenomenon is most likely linguistic in nature.

**Figure 15:** Relationship of social and linguistic factors for patterns of postaspiration duration<sup>44</sup>



**Figure 16:** Relationship of social and linguistic factors for patterns of postaspiration duration



<sup>44</sup> Higher education and University education levels were combined as a result of a few zeros in the distribution of age, education level and types sibilant realizations.

### 5.6 *Results summary*

In conclusion, a bipartite statistical analysis showed that only one linguistic factor, the place of articulation of the following voiceless occlusive, is a reliably significant predictor of the presence of postaspiration while all three linguistic factors, the place of articulation of the voiceless occlusive, the position of the target cluster and the location of the lexically stressed vowel, are reliably significant predictors of the duration of postaspiration when it is present. Also, the phonetic realization of the underlying sibilant in the target clusters shows a significant pattern in that both reduced variants, the aspirated [h] and the phonetic zero [Ø], are produced in conjunction with longer durations of postaspiration. Then, the duration of all adjacent segments were shown to have significantly negative correlations with the duration of postaspiration. More specifically, as the duration of the combined duration for the preceding vowel and the phonetic realization of the underlying /s/ in the target cluster decreases, the duration of postaspiration increases. Finally, social trends not found to be significant by the statistical models due to the integration of speaker as a random factor show, based on tendencies, that it is more likely for younger generations and those with a trade school or university education to produce longer postaspiration durations. The combined results of this section show that the most robust predictors of this postaspiration phenomenon are linguistic in nature and that articulatory trade-offs may be working as the internal mechanisms driving its development.

## 6. Theoretical Analysis

Through the data and statistical analyses provided, it is clear that a complex relationship between the conditioning factors of postaspiration of voiceless occlusives following an underlying sibilant exists in the dialect of Spanish spoken in Seville, Spain. A combination of co-occurring linguistic factors, including the place of articulation of the occlusive, the type of word boundary involved, the position of lexical stress and the phonetic realization of the underlying sibilant /s/, has been shown to condition the duration of postaspiration of the voiceless occlusives /p/, /t/ and /k/. Thus, to better analyze the mechanisms of this linguistically motivated sound change, the theoretical framework of Articulatory Phonology will be employed. To summarize from Section 2.2, Articulatory Phonology is a theoretical model developed by Catherine Browman and Louis Goldstein in the late 1980's that provides a framework that relates the discrete phonemes of phonological representations and the dynamic physicality of natural speech in phonetic realizations. The fundamental aspect of this theory is twofold: first, the use of articulatory movements or gestures as the most basic units of phonological contrast and second, their organization into spatiotemporal patterns (Browman and Goldstein 1992).

Specifically in regards to the data presented here, an understanding of the articulatory gestures involved in the phonetic realizations of the underlying sibilant /s/ and the voiceless occlusives is essential. Each phonetic realization can be broken down into a series of gestural descriptors that specifies the articulators involved, the location of the contact of the articulators and the degree to which the airflow is constricted. When aligned on a spatiotemporal gestural score, the coordination of the gestures for the underlying /s/ realizations and the following voiceless occlusives can help explain the innovative postaspiration phenomenon found in this dialect.

To begin, the gestures involved in the production of the three occlusive consonants analyzed in this study, /p/, /t/ and /k/, are similar in the manner of articulation and differ only the activation of different track variables<sup>45</sup>. All three voiceless occlusives are produced with the same laryngeal gesture in conjunction with three distinct oral gestures associated with different track variables. The laryngeal gesture present in the production of all three consonants is a glottal spreading gesture with a wide constriction degree as the airflow is unrestricted since the vocal chords are not vibrating, a characteristic of voiceless consonants. The distinctive acoustic signals of /p/, /t/ and /k/ are a result of the nature of the oral gestures associated with each occlusive, not the laryngeal gesture. First, the articulators involved for the bilabial consonant /p/ are the lips and the constriction degree is closed as the airflow from the glottal spreading gesture is completely restricted. Second, the dental consonant /t/ involves the tongue tip articulator and the constriction degree is also closed. Finally, the velar consonant /k/ is produced with a closed constriction at the velum using the tongue body articulator. Thus, all three voiceless occlusives are produced with a combination of unrestricted airflow from the open glottis and a closed constriction in the oral cavity through the use of either the lips, tongue tip or tongue body articulators. As for the alignment of these gestures on the spatiotemporal spectrum, almost simultaneous beginning and ending of each gesture results in a voiceless occlusive without the presence of significant durations of postaspiration, which is the production most common in Standard Spanish<sup>46</sup>.

Next, three possible phonetic realizations of the underlying sibilant were presented in this study: a fully realized sibilant [s], an aspirate [h] and an elided phonetic zero [Ø]. First, a fully

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<sup>45</sup> A track variable can be defined as the dimensions that characterize the location of the constriction and the specific articulators involved. For example, the track variable of for lip protrusion involves the upper lip, lower lip and jaw articulators.

<sup>46</sup> It is important here to note that the alignment of the beginning and ending of any particular gesture is gradient in nature. As a result, a short duration of postaspiration (or VOT) is commonly identified on spectrograms for voiceless occlusives in Spanish. However, significantly longer durations, such as those found for syllable initial voiceless stops in English, are of particular interest for this study.

realized voiceless sibilant [s] is produced through the coordination of one laryngeal gesture and one oral gesture; more specifically, a glottal spreading gesture and a tongue tip constriction at the alveolar ridge. The glottal gesture has a wide constriction degree because the airflow is unrestricted since the vocal chords are not vibrating. On the other hand, the oral gesture has a critical constriction degree as the airflow is severely restricted at the alveolar ridge but not completely blocked. This critical constriction degree is characteristic of fricatives and sibilants. For the production of this sibilant, both of these gestures would be aligned temporally, beginning and ending at relatively the same time.

The second possible phonetic realization of the underlying sibilant is the aspirate [h]. It is produced with only one laryngeal gesture, which is the same wide glottal spreading gesture discussed above for the voiceless occlusives and the sibilant /s/. According to Romero (1995), an aspirated sibilant consists of the loss of the oral constriction gesture present for the fully realized sibilant, while maintaining the open glottal gesture. The elimination of only one of the two characteristic gestures of /s/ resulting in aspiration is evidence to the fact that the aspirate [h] is a reduced variant of the underlying sibilant.

The final variant of the underlying sibilant is the complete elision of any phonetic realization, or a phonetic zero [Ø]. In line with the concept of gestural reduction discussed above for the aspirated variant, it is possible to assert that this realization is the result of a complete loss of both the laryngeal gesture, present for both the fully realized variant [s] and the aspirated variant [h], and the oral gesture, present only for the fully realized [s]. While this is a possibility, the data presented in this current study show that both aspirated and elided sibilants pattern similarly, with longer postaspiration durations than the sibilant [s]. This fact lends itself to the

idea that both reduced variants should consist of the same glottal gesture and differ only in their spatiotemporal organizations.

To further explore this theoretical possibility, it is important to explain one of the central tenets of Articulatory Phonology, which states that the coordination of independent gestures on a spatiotemporal gestural score allows for potential overlap among gestures, “from no overlap to complete synchrony” (Browman and Goldstein 1989, 78). This means that gestures are able to move along the temporal spectrum, beginning and ending at different times, resulting in different organizations of gestures. One consequence of this potential temporal movement is gestural hiding, in which with sufficient overlap it is possible for one gesture to completely obscure another gesture, rendering it acoustically inaudible. Notably, the two gestures involved in this hiding must be on different articulatory tiers, meaning that they are produced with different articulators, as to ensure no competition in the completion of both tasks. One example of this would be in the production of the English phrase “perfect memory”. When spoken rapidly, the oral gesture required for the production of the bilabial nasal /m/ in first syllable of *memory* is capable of hiding the tongue tip closure for the alveolar stop /t/ in the last syllable of *perfect*. That is to say, the closing of the lips for the production of the bilabial /m/ masks the acoustic signal of alveolar /t/ and renders it inaudible in rapid speech and results in the phrase being perceived as “perfe[km]emory” (Browman and Goldstein 1989).

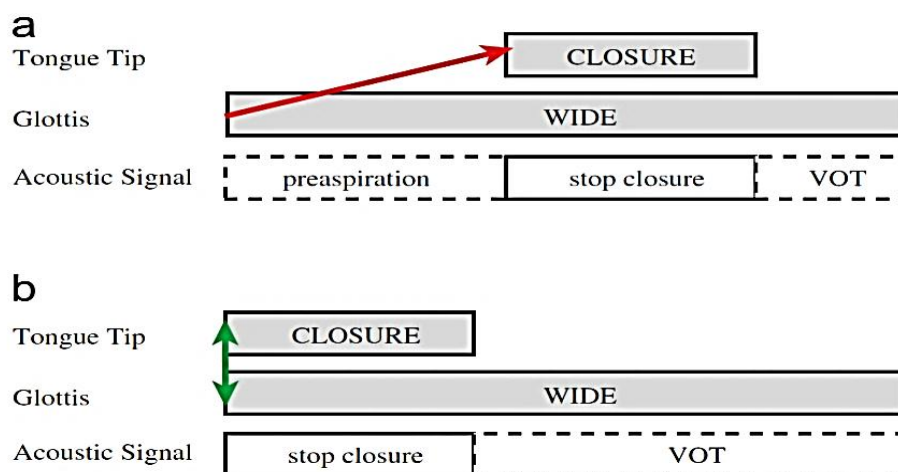
Thus, it is proposed in this study that the same mechanisms responsible for the hiding of the acoustic signal of the alveolar /t/ in the English phrase “perfect memory” are at work in the hiding of the acoustic signal of both of the reduced variants of the underlying sibilant /s/, the aspirate [h] and the elided [Ø]. That is to say, the articulatory gestures involved in the production of the aspirate [h] and the phonetic zero [Ø] are in fact the same. However, their acoustic signal

is different due to the fact that the closed constriction of the following voiceless occlusive can slide along the temporal spectrum. For the aspirated [h], the closure gesture for the following occlusive starts after the beginning of the wide glottal gesture, resulting in a period of audible preaspiration. On the other hand, the elided sibilant is produced in the same manner as the aspirated variant but the closed constriction gesture of the following occlusive slides along the temporal spectrum and begins simultaneously with the wide glottal gesture, subsequently rendering the preaspiration inaudible.

The concept of gestural coordination resulting in the loss of the acoustic signal of preaspiration is investigated in Parrell (2011) where he uses the idea that each articulatory gesture is associated with a clock that is responsible for triggering its activation (See Goldstein, Byrd, Saltzman 2006 for further discussion). The two gestural scores posited by Parrell (2011) in Figure 17 below demonstrate the effects that different relative clock organizations can have on the presence of an aspirated variant [h] and postaspiration of the following voiceless occlusive. First, 17(a) graphically represents the presence of an acoustic signal of aspiration of the underlying sibilant due a wide glottal gesture, followed by the closure for the occlusive and then a relatively short postaspiration duration. The gestures of this clock organization are said to be in an “anti-phase” relationship, or a sequential relationship, because the tongue tip gesture for the occlusive begins after the start of the glottal gesture for the aspirated sibilant. Second, 17(b) shows a representation of the hiding of the laryngeal gesture for the underlying sibilant by the tongue tip closure for the occlusive, resulting in an acoustic signal consisting only of the closure for the occlusive and a relatively long postaspiration duration. This organization is representative of an “in-phase” relationship, or a simultaneous relationship, in which both the glottal and the tongue tip gestures begin at the same point on the temporal scale.



**Figure 17:** *Schematic Gestural Organization for a /Vs.CV/ Sequence in Andalusian Spanish in which (a) represents preaspiration of a voiceless occlusive consonant [<sup>h</sup>C] and (b) represents the postaspiration of a voiceless occlusive consonant [C<sup>h</sup>]*<sup>47</sup>



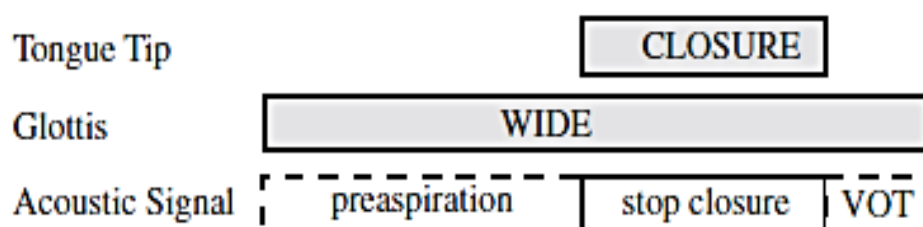
In both 17(a) and 17(b), all of the gestures overlap for an apparently equal amount of time; however, it is the location of the closure along the temporal spectrum in relation to the glottal opening that provides an explanation of the two possible reduced variants of the sibilant, aspirated or elided, and their relationship to longer postaspiration durations. Thus, since the glottal gesture must be present in order to produce the aspiration associated with postaspiration, the elided sibilant must result from a loss of oral constriction gestures, similar to that of aspirated sibilants, but in conjunction with a simultaneous beginning with the closure for the voiceless occlusive. That is to say, the production of the elided sibilant arises from the oral gesture for the closure of the occlusive being in a complete in-phase relationship with the glottal gesture resulting in the loss of audible preaspiration.

The results for this current study have shown that the use of either an in-phase or anti-phase gestural alignment is not categorical and variation exists depending on different linguistic environments. The results of several correlation tests in Section 5.4 provide insight into the trade-off relationships present in the realignment of gestures for these particular consonant

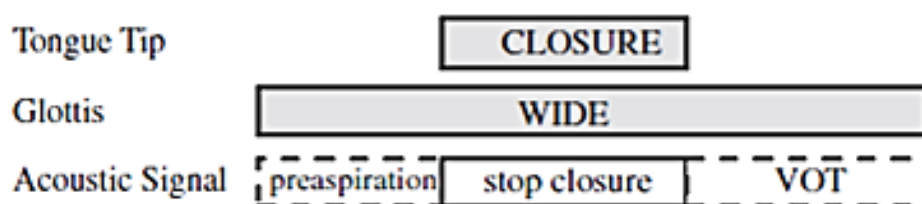
<sup>47</sup> Where C is a voiceless occlusive. Parrell (2011) p. 38

clusters. A statistically significant negative correlation was found between the phonetic realization of the underlying sibilant and the duration of the postaspiration. Taken from Parrell (2011), the gestural scores in Figures 18 and 19 demonstrate the inverse relationship.

**Figure 18:** *Schematic gestural organization for a /Vs.CV/ sequence in Andalusian Spanish with a longer preaspiration and a shorter postaspiration duration*<sup>48</sup>



**Figure 19:** *Schematic gestural organization for a /Vs.CV/ sequence in Andalusian Spanish with a shorter preaspiration and a longer postaspiration duration*<sup>49</sup>



The duration of the wide glottal gesture is not affected in any way, instead it is the temporal location of the closure that determines how much unrestricted air from the glottis escapes either before or after the closure, resulting in either pre or postaspiration. With a longer duration of preaspiration, a shorter postaspiration duration is expected, as in Figure 18, and with a shorter duration of preaspiration, a longer postaspiration duration is predicted, as in Figure 19.

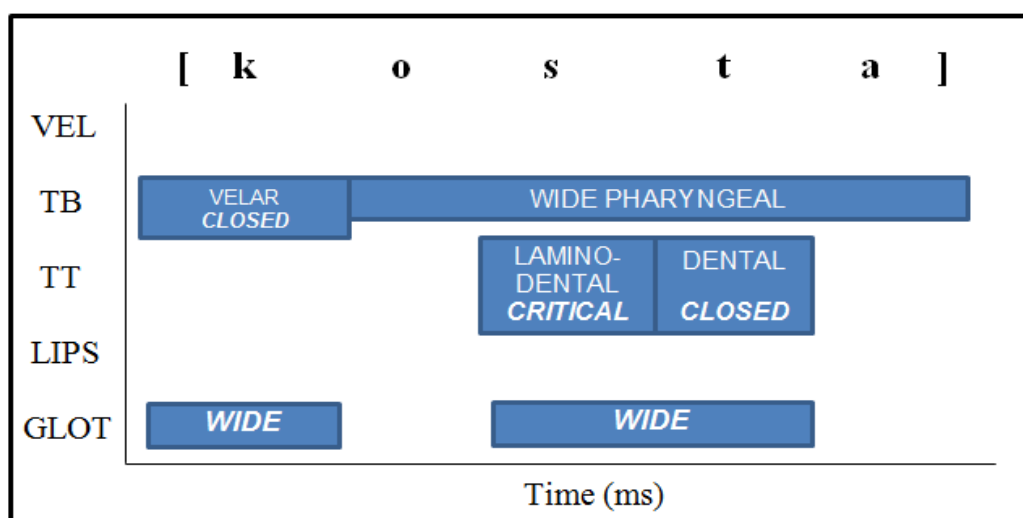
It is noteworthy to mention that only the relationship of the reduced variants, the aspirated [h] and the phonetic zero [Ø], to postaspiration are explained in Figures 18 and 19. The next logical step is to understand why the results of this study found that the production of a fully realized sibilant does not result in long durations of postaspiration with the same frequency as

<sup>48</sup> Where C is a voiceless occlusive. From Parrell (2011) p. 42

<sup>49</sup> Where C is a voiceless occlusive. From Parrell (2011) p. 42

the reduced variants. As has been seen above, longer durations of postaspiration arise from the overlapping of one open laryngeal gesture and one oral closure gesture. In the case of a fully realized sibilant followed by an occlusive consonant, two oral gestures are present in the gestural organization, a tongue tip constriction for the sibilant and a closure constriction for the occlusive, along with the open laryngeal gesture. As seen in Figure 20 below, the oral gesture associated with the sibilant is already in an in-phase relationship with the beginning of the wide glottal gesture.

**Figure 20:** *Proposed gestural score for the Spanish word costa “coast” produced with a fully realized sibilant /s/*<sup>50</sup>



As a result of this stable relationship between the oral gesture and the laryngeal gesture for the sibilant, there is no impetus for the closure gesture of the following occlusive to overlap the previous oral gesture<sup>51</sup>. The consonant cluster then is produced sequentially and both acoustic

<sup>50</sup> The organization of the gestural scores presented here is taken from Browman and Goldstein 1989. The Y axis consists of the possible articulators (VL=Velum, TB=Tongue Body, TT=Tongue Tip, LIPS=Lips, GLOT=Glottis). The X axis represents time.

<sup>51</sup> The cluster [st] is represented here, but the same analysis applies to [sp] and [sk] as well. The only difference lies in the tier on which the closure gesture is present. In the case of the bilabial [p], the closure gesture would be placed sequentially after the laminodental closure on the LIPS articulatory tier with the lips as the articulator and closed as the type of constriction. As for the velar [k], the closure gesture would be placed sequentially after the laminodental

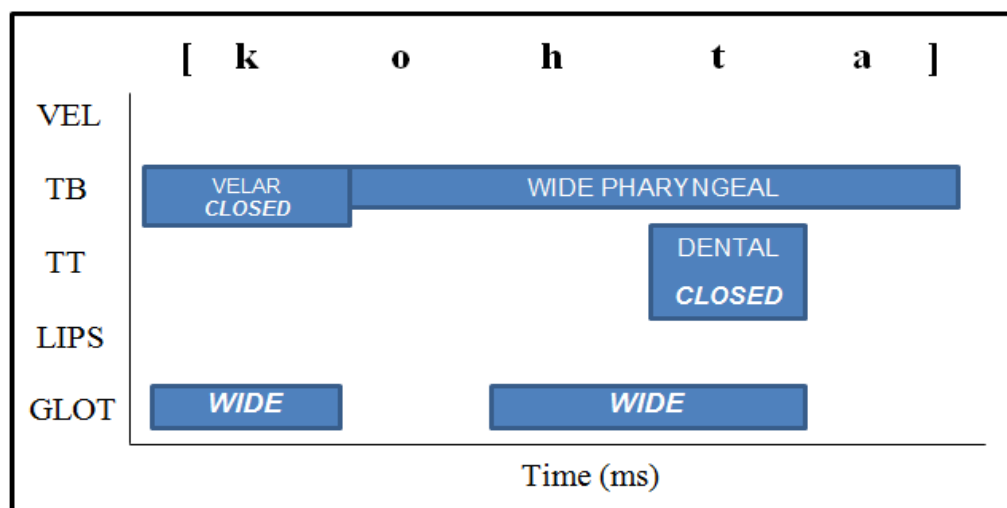
signals are produced and perceived without disruption. Additionally, Browman and Goldstein (1989, 1992) discuss the inherent durations of different types of articulatory gestures. Due to physiological constraints on the vocal tract, the potential duration of a wide glottal gesture is limited. Thus, once the sequential production of both the tongue tip gesture for the sibilant and the relevant constriction for the following occlusive consonant are completed, the wide glottal gesture is no longer able to continue and does not extend past the release of the occlusive.

Consequently, the articulatory motivation for the reduction of the fully realized sibilant to either reduced variant through the loss of the oral gesture merits discussion. According to Romero (1995), the Andalusian Spanish sibilant /s/ is typically characterized as laminodental, in contrast with the apical sibilant of Northern Spanish dialects. He says that the laminodental /s/ typically consists of “smaller, shorter and slower movements than an apical /s/” (136) and as a result, is more easily reduced to the aspirated variant. Thus, Figure 21 below proposes a gestural score in which the laminodental sibilant is reduced to aspiration through the loss of the critical tongue tip constriction. Following the proposal by Parrell (2011), the unstable anti-phase relationship in Figure 21 would soon give way to a more stable in-phase relationship in which the oral gesture consisting of a closed tongue tip constriction would slide along the temporal spectrum to begin simultaneously with the wide glottal gesture. The reorganization of the gestures would then result in the glottal gesture responsible for aspiration to extend past the release of the dental tongue tip closure for the occlusive /t/ causing postaspiration. This is shown in Figure 22 below.

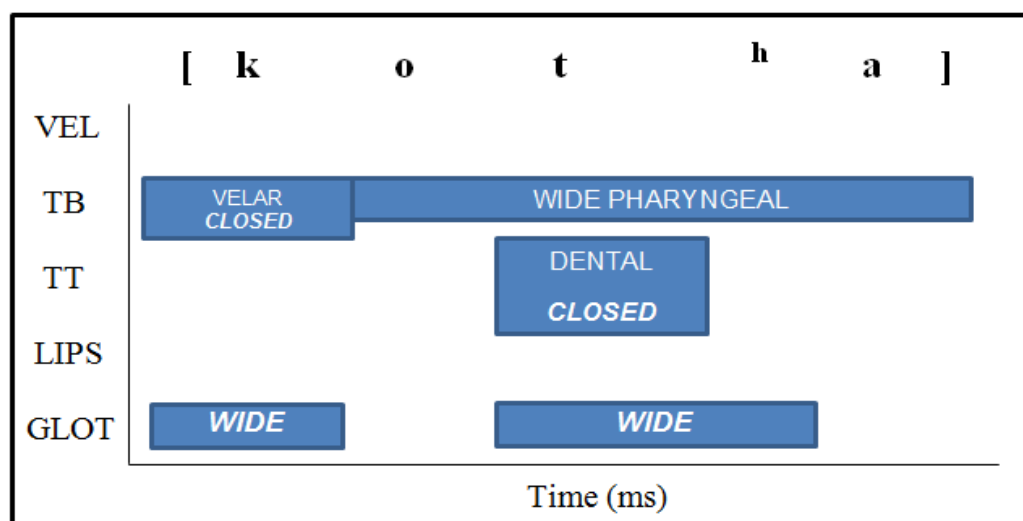
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closure on the VEL (velum) articulatory tier with the tongue body as the articulator and closed as the type of constriction.

**Figure 21:** *Proposed gestural score for the Spanish word costa “coast” produced with an aspirated sibilant [h]<sup>44</sup>*



**Figure 22:** *Proposed gestural score for the Spanish word costa “coast” produced with the underlying sibilant as a phonetic zero [Ø] and long postaspiration<sup>44</sup>*



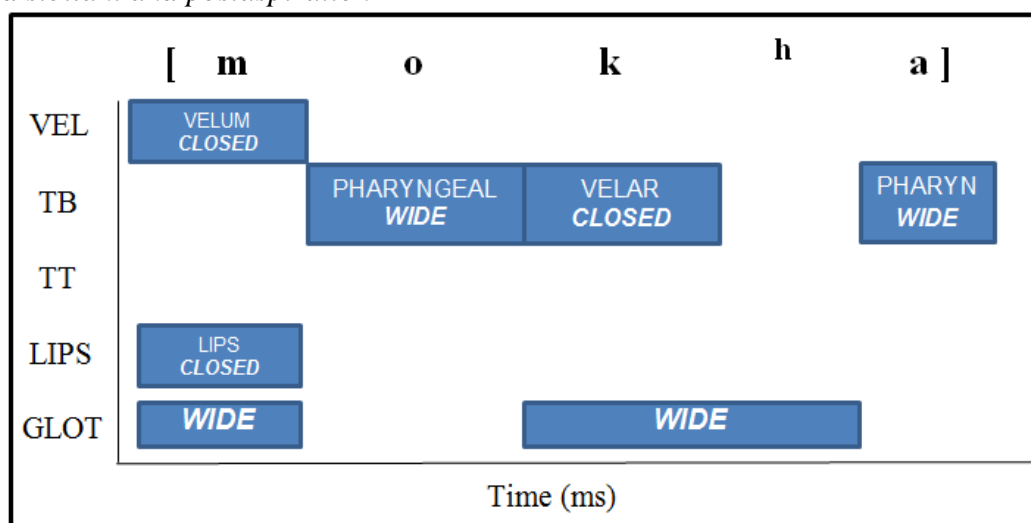
Additionally, the results of this current study have found that other linguistic variables, not just the phonetic realization of the underlying sibilant or the place of articulation of the following occlusive, also condition the duration of postaspiration. First, the position of the target cluster in regards to morphological boundary was found to be a predictor of postaspiration duration. When located word internally, postaspiration was significantly longer than when across

a word boundary, where postaspiration was found to be significantly shorter. Additionally, high rates of phonetic zeros that pattern with longer postaspiration due to an in-phase relationship were found in word internal environments, while higher rates of aspirated variants existing in an anti-phase relationship were found in word external environments with shorter postaspiration. Notably, in a recent electropalatography (EPG) study, Cho (2001) found that intergestural timing is more stable within a single lexical item and significantly less stable across word boundaries. This is congruent with Parrell (2011) in that the most stable gestural organization is that of an in-phase relationship where both gestures begin simultaneously. Thus, the most stable timing of gestures occurs more with an in-phase gestural alignment in a word internal environment, which is found in the data for the current study with high rates of phonetic zeros in this particular linguistic context.

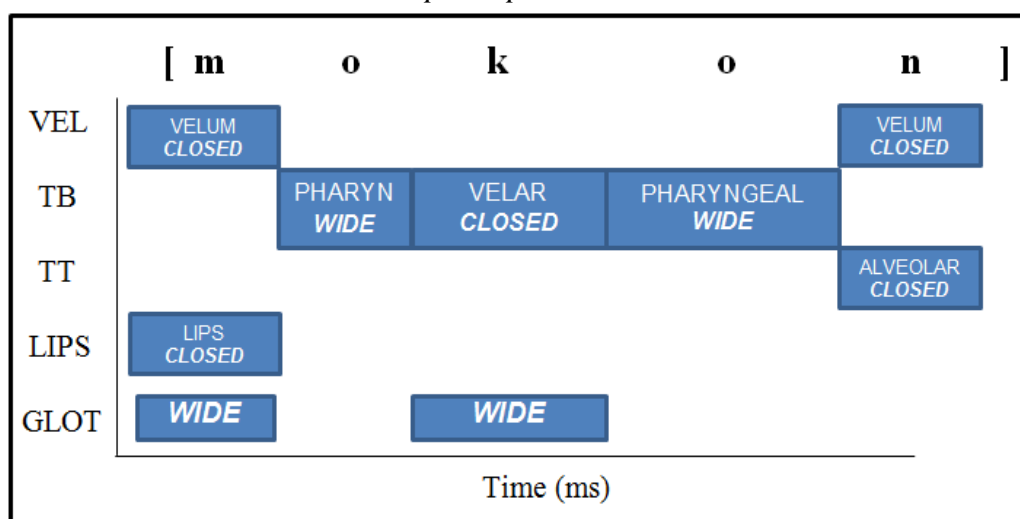
The final linguistic environment found to be a significant predictor of postaspiration duration is that of a preceding stressed vowel. Since it is found cross-linguistically that stressed syllables are longer in duration than unstressed syllables, it is posited here that the increased duration of the syllable containing the underlying sibilant results in a longer duration of the wide glottal gesture. With a longer internal duration of the unrestricted airflow from the glottis, it is possible that when the closure gesture and the glottal gesture are realigned to begin simultaneously, more aspiration is likely to extend past the release of the occlusive. This gestural difference is demonstrated in the Figures 20 and 21 below. In Figure 20, the first syllable of the Spanish word *mosca* “fly” carries the lexical stress so all gestures involved are longer in duration. Most notably, the wide glottal gesture has a longer duration due to its location in a stressed syllable and as a result, extends past the release of the following velar occlusive /k/. In contrast, Figure 21 shows a proposed gestural score for the same /sk/ consonant cluster but in the

environment of a following stressed vowel in the Spanish word *moscón* “large fly”. Since the wide glottal gesture is not a part of the stressed syllable, its duration is shorter and as a result, does not extend past the release of the following velar consonant.

**Figure 20:** *Proposed gestural score for the Spanish word ‘mosca’ ‘fly’ with preceding stress, an elided sibilant and postaspiration*



**Figure 21:** *Proposed gestural score for the Spanish word ‘moscón’ ‘large fly’ with following stress, an elided sibilant and nonexistent postaspiration*



To summarize, the theoretical framework of Articulatory Phonology allows for an extensive and comprehensive account of the gradient nature of the postaspiration phenomenon occurring in Seville, Spain. All four linguistic predictors including the phonetic realization of the

underlying sibilant, the place of articulation of the following occlusive, the type of word boundary and the position of stress in relation to the target cluster are able to be incorporated into the theoretical model in order to demonstrate their influence on the presence and duration of postaspiration.

However, there are critics of Articulatory Phonology that remain adamant that the underlying phonological representations are inherently separate from their phonetic realizations. One such example is an experiment conducted by O'Neill (2009) about /s/ aspiration and voiceless occlusions in Andalusian Spanish. He investigated both preaspiration and postaspiration of the voiceless alveolar fricative in the phonological context of a following voiceless occlusive. He posits that the timing of gestures is not the impetus for postaspiration but instead it is the presence of an underlying aspirated phoneme, instead of an underlying sibilant. His study involved analyzing the closure duration of the occlusive and duration of the vowel preceding the sibilant in a word such as *pasta* “pasta”, pronounced as either [pa<sup>h</sup>t<sup>h</sup>a] or [pat<sup>h</sup>a], in comparison to words such as *pata* “leg”, pronounced [pa.ta]. Using his results, O'Neill suggests that for the first word type in which an underlying sibilant is orthographically present, two phonological representations exist for Andalusian Spanish speakers. The first is the standard phonological organization /Vs.OV/<sup>52</sup> that consists of four underlying phonemes that correlate with the surface realization. The second representation posited by O'Neill is /V.O<sup>h</sup>V/, which includes only three underlying phonemes resulting from a loss of /s/ as an underlying segment and the addition of an underlying aspirated voiceless occlusive to the phonological inventory of certain Andalusian speakers. This new phonological representation is supported by a correlation of vowel durations found in his data between the first vowel in the words with orthographically closed syllables, such as *pasta*, and the first vowel in those with an orthographically open

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<sup>52</sup> Where /O/ is a voiceless occlusive



syllable, such as *pata*. He states that since the two vowels are similar in duration, a word such as *pasta* must no longer consist of a closed syllable in the minds of the speakers, meaning that the underlying /s/ is categorically lost and the aspiration is arising from a distinct set of voiceless aspirated occlusive phonemes for Andalusian dialects. In light of all the previous works, especially that of Torreira (2012), which showed clear correlational evidence against the presence of a new aspirated phoneme in conjunction with the relatively high rates of fully realized sibilants in the data of the current study, I find this claim to be extreme. Although the data from O'Neill (2009) brings interesting information to light about the effect of reduced variants of the underlying sibilant /s/, Articulatory Phonology is capable of explaining changes in duration, both of vowel length and pre and post aspiration. Browman and Goldstein (1986, 1989, 1992) have clearly stated that gestures may expand or contract along the temporal spectrum, thus allowing for duration changes of both consonants and vowels. In conclusion, Articulatory Phonology provides a strong theoretical model for representing the underlying articulatory gestures that account for the varying postaspiration productions found in Seville Spanish.

## Section 7: Conclusion

The current study has provided a comprehensive acoustic study of the postaspiration of voiceless occlusive consonants in the dialect of Spanish spoken in Seville, Spain. The main objectives of the study were threefold: to investigate the postaspiration phenomenon of the voiceless dental stop /t/ when preceded by the sibilant /s/ and its possible extension to the voiceless bilabial stop /p/ and the voiceless velar stop /k/, to document the social and linguistic factors conditioning this innovative postaspiration and to analyze this sound change from the perspective of Articulatory Phonology. In order to address these objectives, a sentence reading task was conducted with 26 native speakers from Seville, Spain.

The first important finding was the high degree of interspeaker variation present in this particular dialect discovered through a series of univariate ANOVAs. Mixed effects models with speaker as a random effect were shown to be the only reliable tests for predicting the independent factors influencing the realization of postaspiration. In the first set of tests, postaspiration was analyzed as a categorical dependent variable, as either present or absent. It was shown that the place of articulation of the following occlusive is the only robust predictor of the presence of significantly long postaspiration. More specifically, the dental and the velar places of articulation patterned similarly in their prediction of longer durations of postaspiration in stark contrast to the bilabial place of articulation, which favored significantly shorter durations. This shows that the phenomenon of postaspiration is no longer limited to the dental occlusive, as previous studies suggest, and has been extended to the velar occlusive but not to the bilabial. In the second set of statistical tests, the duration of postaspiration was treated as a continuous dependent variable and only the tokens consisting of positive durations of postaspiration were included. This permitted an investigation of the factors conditioning the

duration of the postaspiration when it is present. It was shown that only the linguistic factors, including the place of articulation of the following occlusive, the location of the lexical stress in relation to the underlying sibilant and the type of word boundary, are reliable predictors of the duration of postaspiration. More specifically, the longest postaspiration durations were found in clusters with a dental or velar occlusive with a preceding stressed vowel in a word internal environment. Notably, no social factors were found to be significant in either set of statistical analyses when speaker was added as a random effect. However, tendencies towards longer durations of postaspiration were found for younger women and speakers with a trade school and university level education.

Also investigated was the effect on postaspiration duration in relation to the phonetic realization by the speaker of the underlying sibilant /s/, as either the fully realized sibilant [s] or one of the two reduced variants, an aspirate [h] or an elision of the segment [Ø]. It was found that the two reduced variants pattern overwhelmingly with longer durations of postaspiration while the fully realized sibilant pattern with significantly shorter durations. This pattern was found across all significant independent variables, both social and linguistic, and suggests that the phenomenon is most likely linguistic in nature.

Finally, the correlation relationships between the duration of the surrounding segments and the postaspiration of the voiceless occlusive were investigated. In agreement with past studies, it was found that a significant negative correlation is present. This means that as the duration of the previous vowel + consonant cluster decreases, the duration of postaspiration increases. This is strong evidence that the linguistic nature of the phenomenon is driven by particular articulatory trade-offs of the sounds involved.

All of these findings were then analyzed and interpreted within the framework of Articulatory Phonology. It was posited that the two reduced variants of the underlying sibilant pattern more frequently with longer durations of postaspiration as a result of different potential gestural organizations. More specifically, a realignment of the oral gesture corresponding to beginning of the following occlusive with the beginning of the wide glottal gesture for the reduced sibilant allows for a potential extension of the aspiration past the release of the occlusive, resulting in long postaspiration.

To conclude, it is clear that future studies are needed in order to better understand the social influences and linguistic constraints conditioning this phenomenon. Since it has been documented as being a relatively recent development and seemingly restricted to the city Seville, Spain, a larger collection of data would allow for a more extensive analysis. Both social and linguistic aspects remain for future research. Socially, a higher number of participants may show more significant differences between age groups, gender and education levels. Linguistically, the use of spontaneous speech data and the effect of speech rate may provide more insight into the alignment and coordination of the gestures involved in the production of these consonant clusters. Finally, a more sociolinguistic account of the language attitudes and levels of prestige associated with long postaspiration of voiceless occlusives within Seville and throughout Spain would allow for a deeper understanding of this phenomenon.

## 8. Appendix: Full list of the stimuli presented to each participant

Es un **gasto** grande. ['gas.to]  
 Voy a la **costa** ahora. ['kos.ta]  
 Quiero hablar con el **pastor** pronto. [pas.'tor]  
 Mando la **postal** hoy. [pos.'tal]  
 Es un **déspota** horrible. ['des.po.ta]  
 La tela es **áspera** allí. ['as.pe.ra]  
 Quiero un **espejo** nuevo. [es.'pe.χo]  
 Hablo con mi **esposo** cada día. [es.'po.so]  
 Prefiero una **rosca** ahora. ['ros.ka]  
 Hay una **mosca** allí. ['mos.ka]  
 Quiero un **roscón** de Reyes. [ros.'kon]  
 Hay un **moscón** en el bar. [mos.'kon]  
 Quiero las **telas** bonitas. [las#'te.las]  
 Trabajan los **telares** buenos. [los#te.'la.res]  
 Esos músicos **tocan** bien. ['mu.si.kos#'to.kan]  
 Esos músicos **tocaron** bien. ['mu.si.kos#to.'ka.ron]  
 Ellos quieren las **tapas** baratas. [las#'ta.pas]  
 Compró las **tapitas** buenas. [las#ta.'pi.tas]  
 Prefiero los **perros** pequeños. [los#'pe.ros]  
 Evito los **perrazos** grandes. [los#pe.'ra.θos]  
 Los mecánicos **comen** en el garaje. [me.'ka.ni.kos#'ko.men]  
 Los mecánicos **comieron** en el garaje. [me.'ka.ni.kos#ko.'mje.ron]  
 Los niños van con los **papás** de paseo. [los#pa.'pas]  
 Compró las **papas** allí. [las#'pa.pas]  
 Esos médicos **pagan** con tarjeta. ['me.'ði.kos#'pa.ɣan]  
 Esos médicos **pagaron** con tarjeta. ['me.'ði.kos#'pa.ɣa.ron]  
 Intento evitar las **colas** largas. [las#'ko.las]  
 Prefiero los **colores** brillantes. [las#ko.'lo.res]  
 Ellos viven en las **casas** de allí. [las#'ka.sas]  
 Pusieron las **casetas** grandes. [las#ka.'sa.tas]

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